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CATAPULT PERFORMANCE AND INTERFACE REQUIREMENTS FOR LAUNCH OF BQM-34 VEHICLES

Teledyne Ryan Aeronautical Company

Prepared for:

Sacramento Air Materiel Area

10 June 1974

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FINAL REPORT
CATAPULT PERFORMANCE
AND INTERFACE REQUIREMENTS
FOR LAUNCH OF BQM-34 VEHICLES

REPORT NO.
TRA 29369-5 10 JUNE 1974

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KEY TERMS

Aerodynamic Loads

Factor of Safety

Launch Boundary

Launch Criteria

Load Factors

Mass Properties

Release Mode

Structural Limit Loads

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1.0 INTRODUCTION AND SUMMARY

This technical report is submitted in accordance with Sequence Number A002 of Form DD1423 under Air Force Contract Number F04606-73-A-0048/SC 18 to provide information for the design of a catapult launcher for the Teledyne Ryan BQM-34A and BQM-34F series of drones.

Information contained herein provides performance and vehicle interface data for an independent contractor to prepare cost estimates for the design and manufacture of a catapult for the aforementioned vehicles. Curves of engine data are provided for various temperature and pressure conditions. Aerodynamic loads for various pitch attitudes up to 250 KEAS are also included. Limit load factor envelopes and limit loads for the present ground launch fittings are also presented in this report.

Conclusions based on the results of a six-degree-of-freedom dynamic simulation study for a catapult launch of a BQM-34A with the LSI A/A37G-8 autopilot are given below. These results are based on a study of drone launch characteristics beginning at release from the catapult shuttle.

a. Catapult launch of the assumed worst case configuration can be best achieved with rpm = 100 percent, θ = 10 degrees, θ_{CMD} = 20 degrees and V_o = 465 feet per second.

b. Lightweight vehicles (2,000 pounds) can be launched at speeds approaching 400 feet per second.

c. In general, pitch attitude commands greater or less than 20 degrees require higher catapult velocities to launch the vehicle considered in the study.

d. Horizontal distance required to achieve an altitude gain of 200 feet is inversely related to θ_{CMD}. The lower (smaller) the command, the longer the distance.

e. Other vehicle configurations must be adequately analyzed to assure successful launch and to establish the most adequate pitch command for each case.

Conclusions based on the results of a six-degree-of-freedom dynamic simulation study for a catapult launch of a BQM-34F with the LSI A/A37G-8 autopilot are as follows:

a. The vehicle should be launched at 10 degrees pitch attitude, and under worst case conditions, at least 450 feet per second catapult launch velocity and the engine running at 100 percent rpm.

b. No autopilot changes are required. The present ground launch pitch attitude command of 25 degrees can be used.

c. Further reductions in velocity can be made by decreasing vehicle weight or by an initial pitch rate.

The drone mechanical and electrical interface requirements, drone capabilities and characteristics and catapult performance requirements treated in this report apply to unmodified vehicles and presently used ground launch provisions. Accomplishment of the design of the catapult, adaptation of the drones for catapult launch, and development of the catapult launch operational procedures, should be regarded as an iterative process with the information presented herein providing the foundation for that effort. Structural interface loads and load reaction points, vehicle separation characteristics, launch trajectory, and effects of different vehicle weights and configuration are a function of the catapult design and require further consideration during the catapult design phase.

2.0 TECHNICAL DISCUSSION

2.1 GENERAL

Two basic configurations have been analyzed during the contract study. These include:

a. BQM-34A - Standard BQM-34A target (Teledyne Ryan Model 124), with a 36-square-foot wing, weight and inertia data scaled up to 3,000 pounds and the addition of a drag increment to compensate for the 11-inch diameter CIR pods.

b. BQM-34F - Standard BQM-34F (Teledyne Ryan Model 166) target with the 6-inch Hayes IR pods, and weight and inertia data scaled to 3,000 pounds.

Additional information for other target vehicles is also included herein. Figure 2-1 is a general arrangement drawing (124V322) for the following configurations: BQM-34A, BQM-34S and the Teledyne Ryan Model 251. Figure 2-2 is a general arrangement drawing (166V4002) for the following configurations: BQM-34F, BQM-34E, and the BQM-34T.

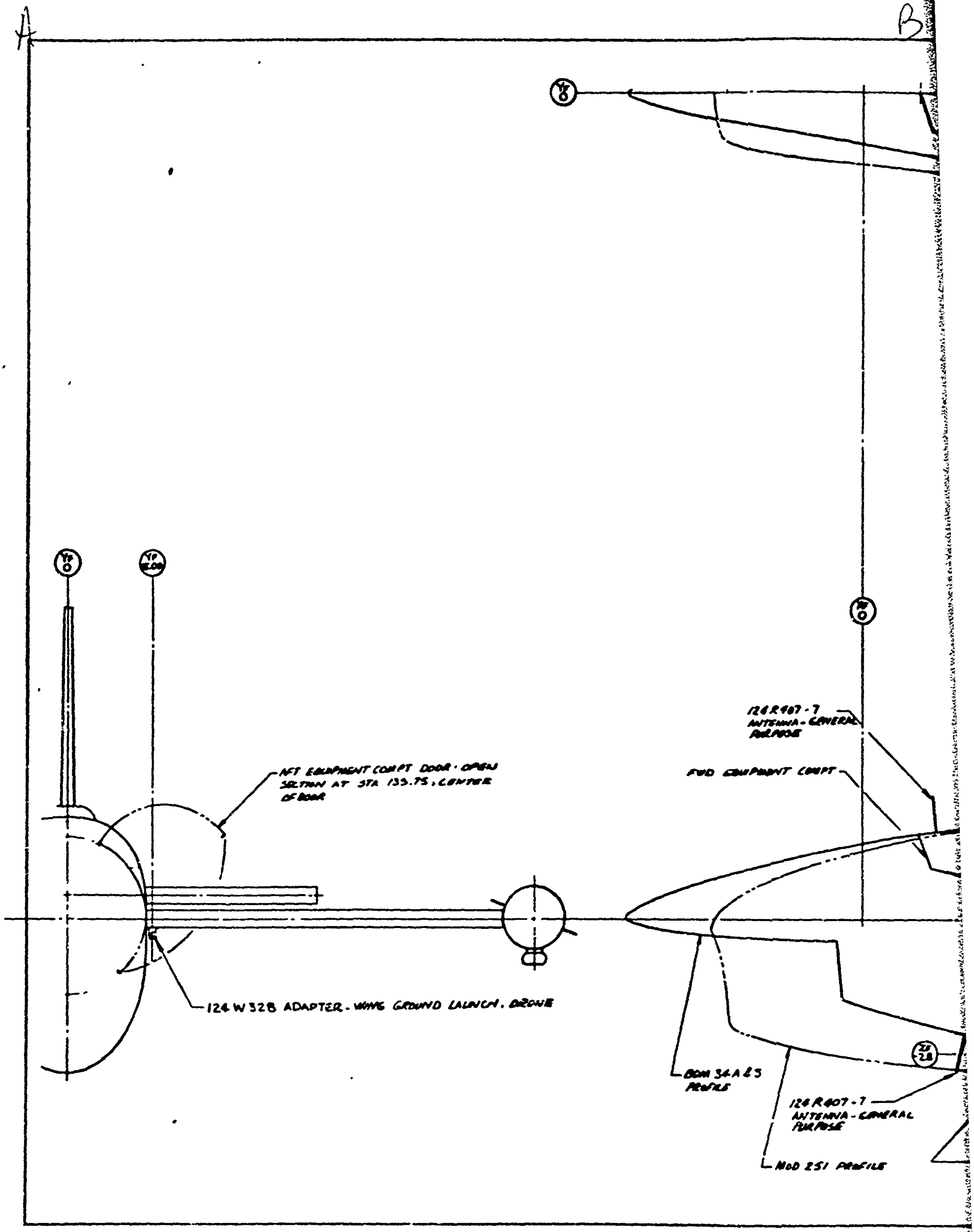
Analyses were conducted based on the following conditions:

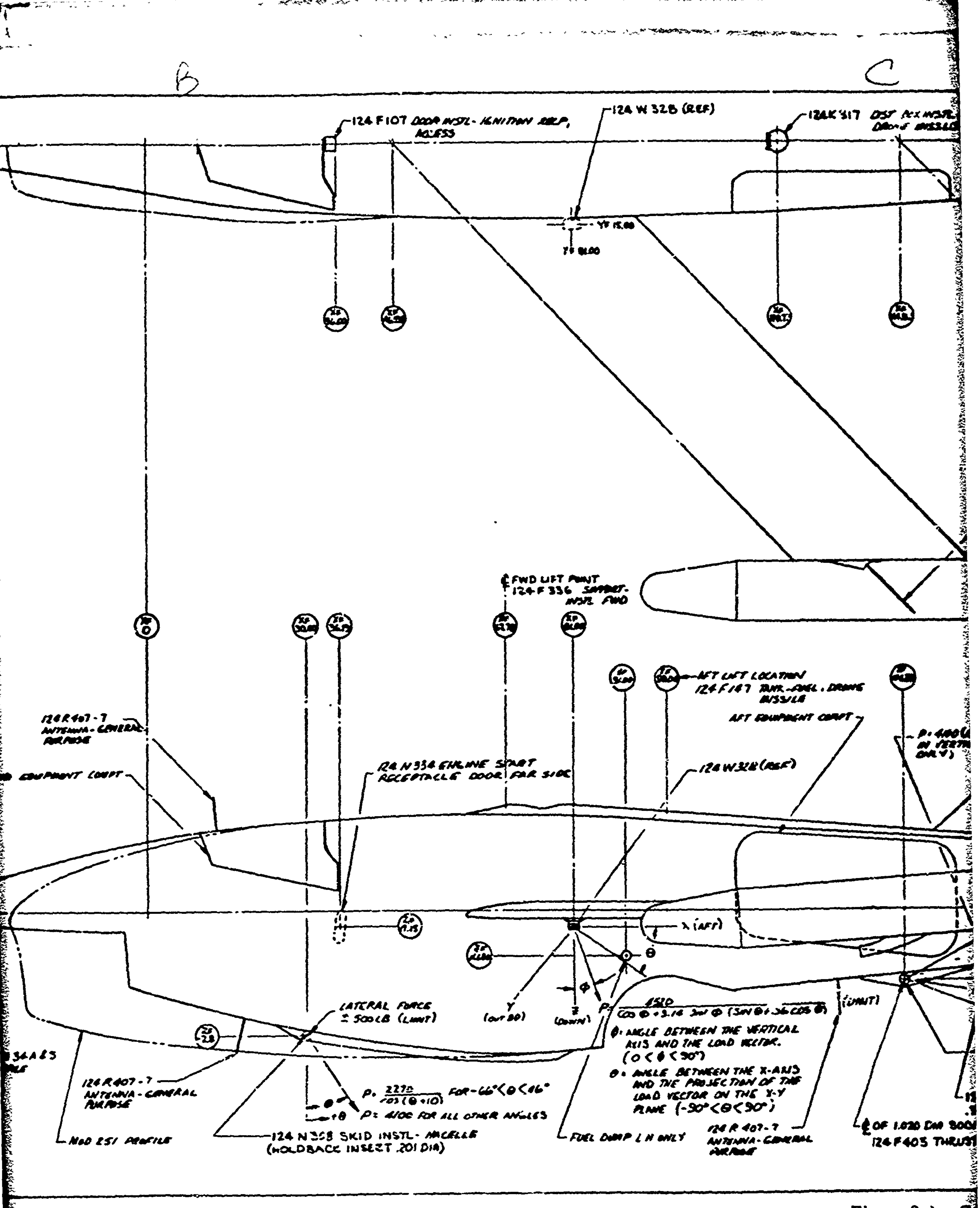
a. Temperature, 105°F

b. Altitude, 5,000 Feet

For the dynamics analysis of the worst case configurations, the maximum temperature at 5,000-foot altitude was reduced from 130°F to 105°F. This decision, although arbitrary, was made on the basis of anticipated percentage of occurrence so as not to impose unrealistic requirements on the catapult.

Throughout this report, assumptions and limitations will be specified and the conditions and configurations used will be described.


A
B
124R407-7 ANTENNA-GENERAL PURPOSE
FWD EQUIPMENT COMPT
AFT EQUIPMENT COMPT DOOR-OPEN SECTION AT STA 133.75, CENTER OF DOOR
124 W 328 ADAPTER-WING GROUND LAUNCH, DRONE
BQM 34A & S PROFILE
124R407-7 ANTENNA-GENERAL PURPOSE
MOD 251 PROFILE



B
C
124 F107 DOOR INSTL - IGNITION RELP, ACCESS
124 W 328 (REF)
124 F 336 SUPPORT INSTL FWD
FWD LIFT POINT
AFT LIFT LOCATION 124 F 147 TANK - FUEL, DRONE MISSILE
AFT EQUIPMENT COMPT
124 R 407-7 ANTENNA - GENERAL PURPOSE
124 N 334 ENGINE START RECEPTACLE DOOR FAR SIDE
124 W 328 (REF)
LATERAL FORCE ± 500 LB (LIMIT)
θ: ANGLE BETWEEN THE X-AXIS AND THE PROJECTION OF THE LOAD VECTOR ON THE X-Y PLANE (-90°<θ<90°)
ϕ: ANGLE BETWEEN THE VERTICAL AXIS AND THE LOAD VECTOR. (0<ϕ<90°)
P = 4100 FOR ALL OTHER ANGLES
124 N 368 SKID INSTL - NACELLE (HOLDBACK INSERT .201 DIA)
FUEL DUMP L H ONLY
124 F405 THRUST

Figure 2-1. G

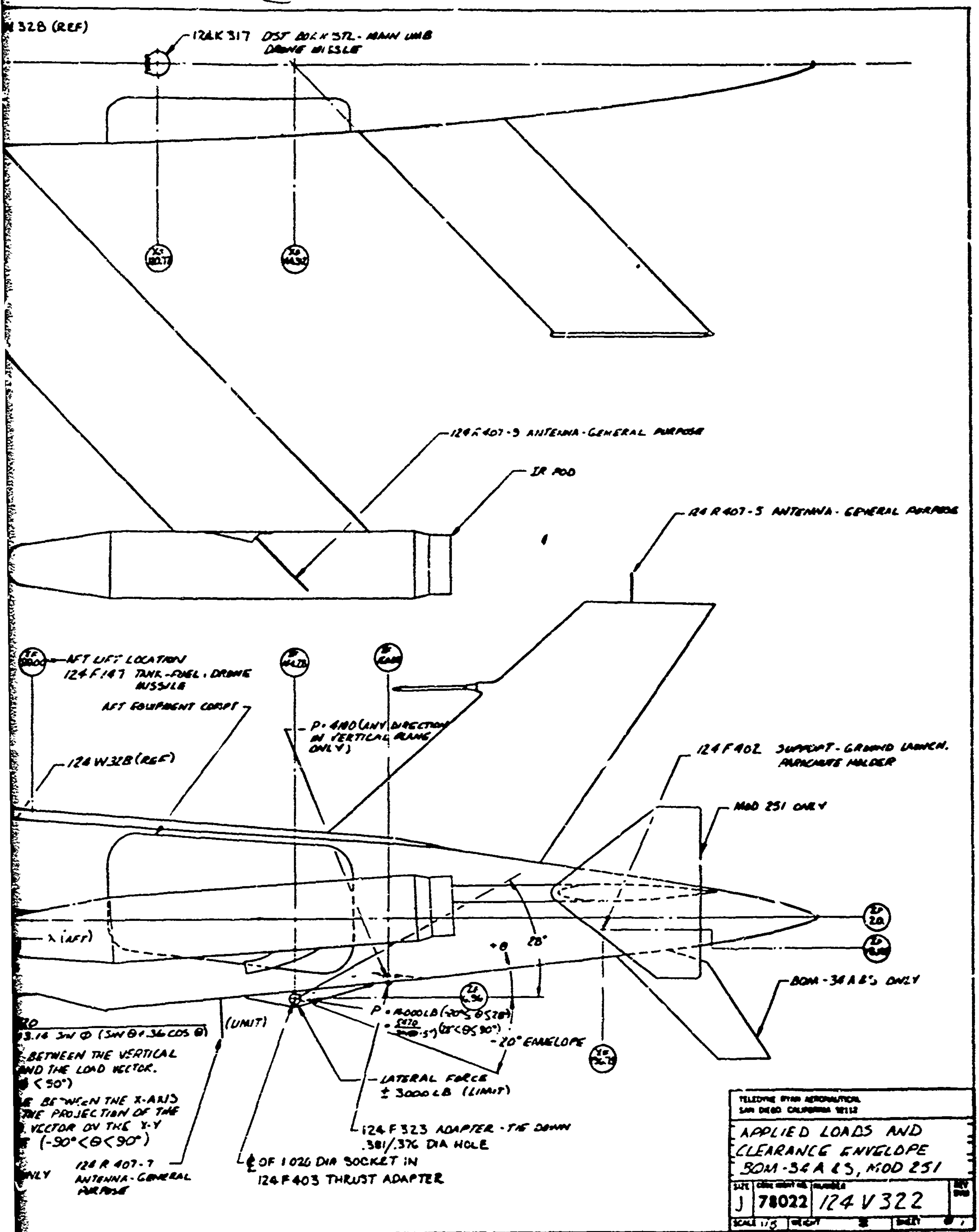


Figure 2-1. General Arrangement, BQM-34A, S, and Model 251

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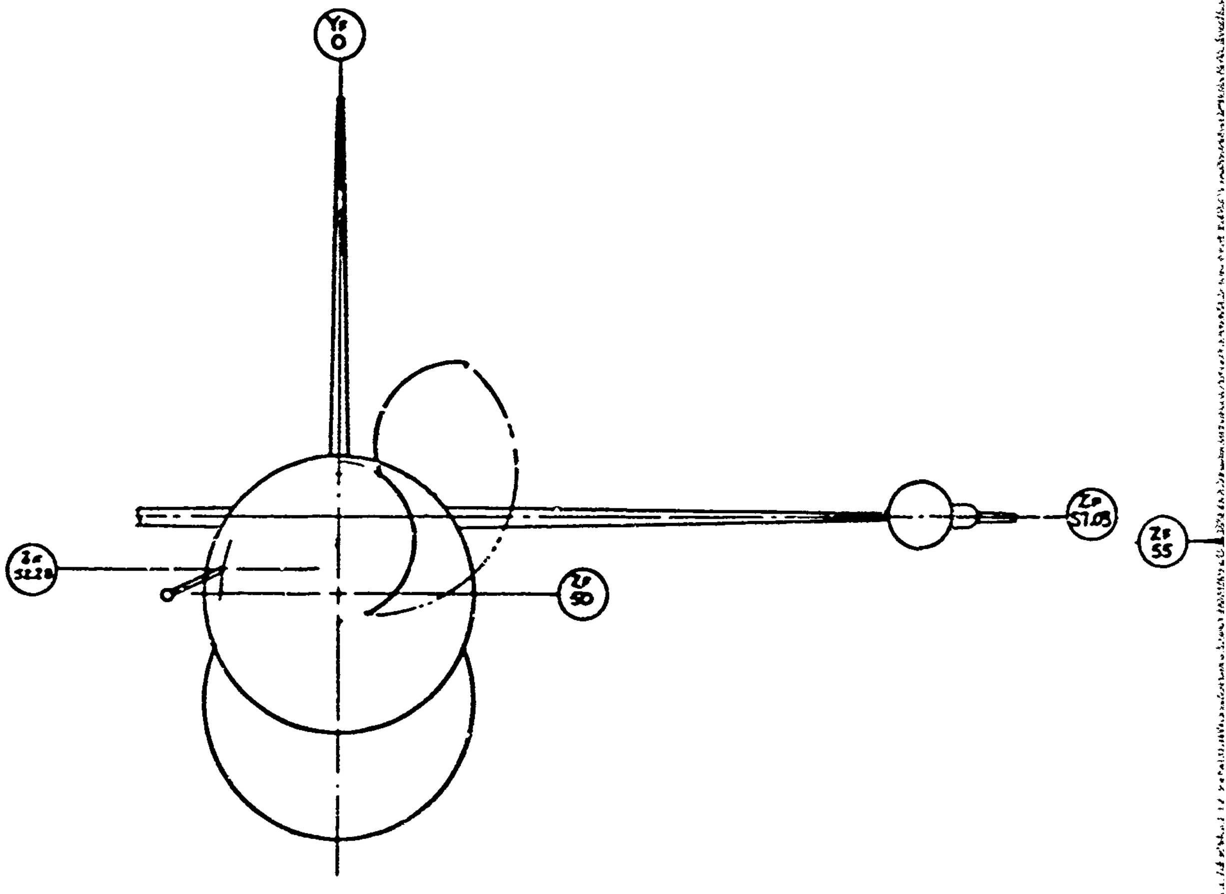
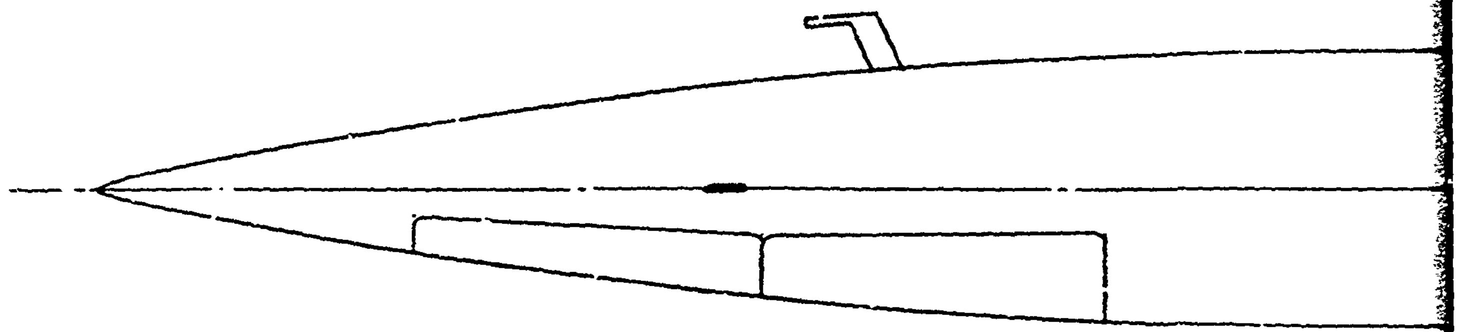
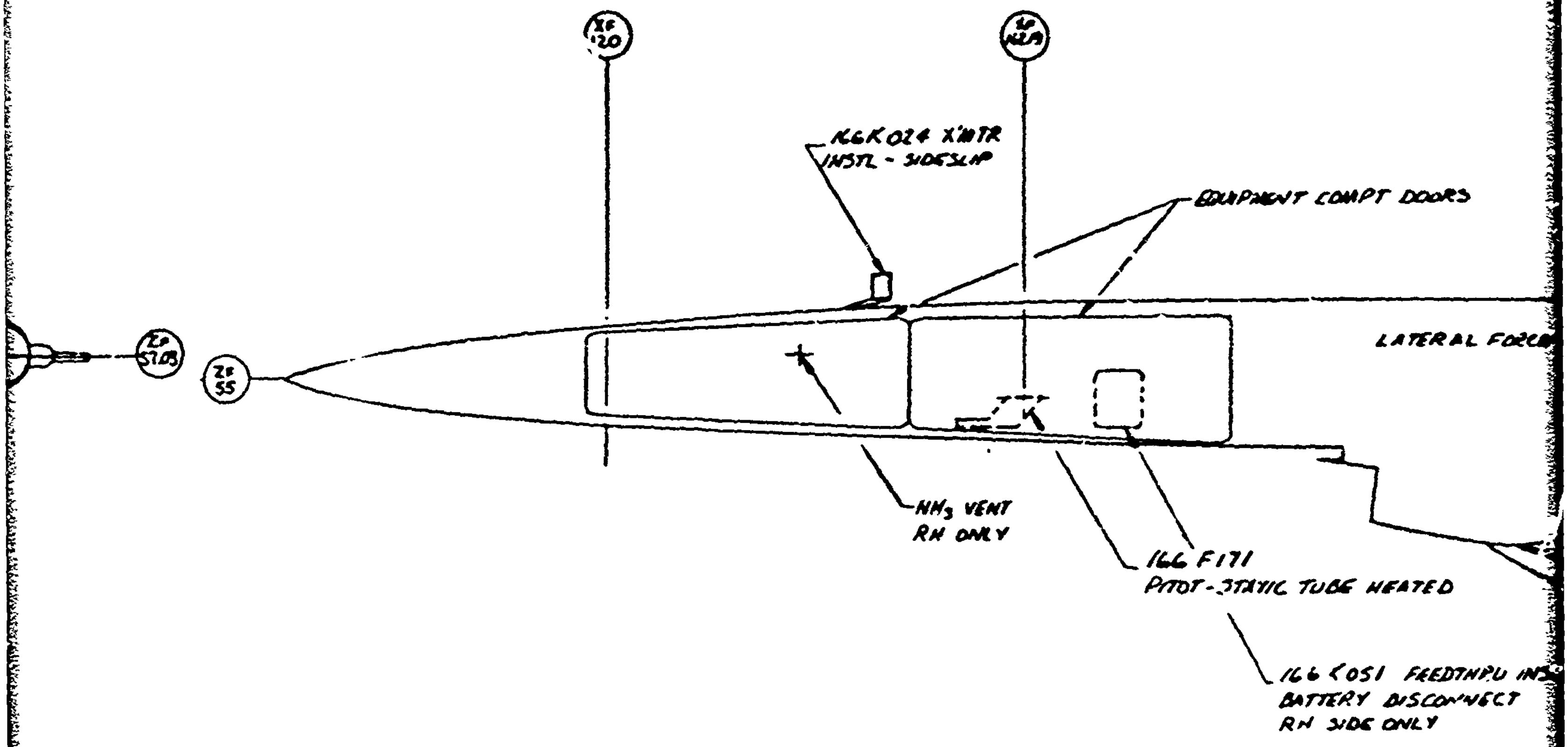
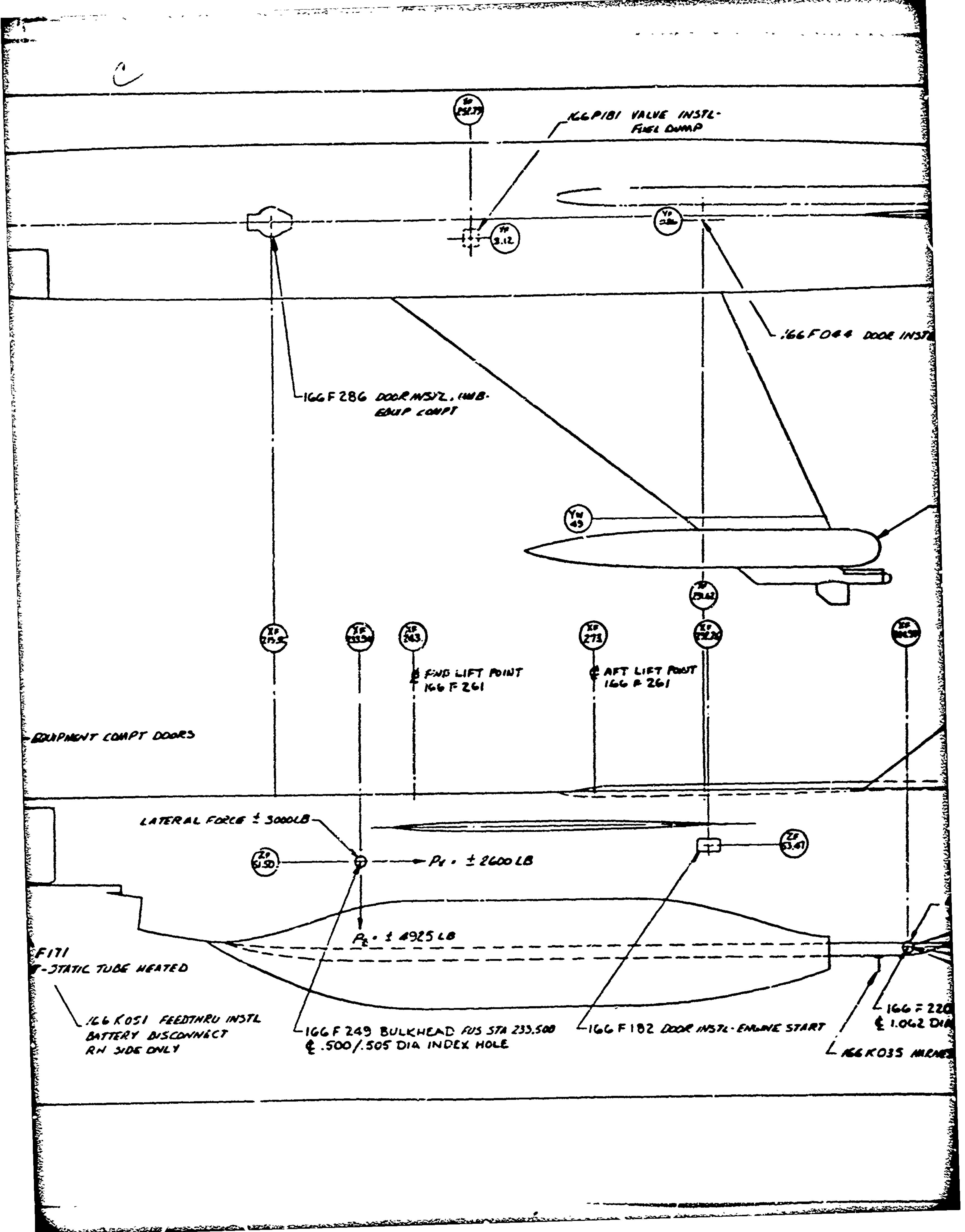
A



B




XF 120
166K024 X'MTR INSTL - SIDESLIP
EQUIPMENT COMPT DOORS
LATERAL FORC
ZF 55
NH_3 VENT RH ONLY
166 F171 PITOT-STATIC TUBE HEATED
166 C051 FEEDTHRU INS BATTERY DISCONNECT RH SIDE ONLY


166P181 VALVE INSTL-
FUEL DUMP
YF 3.12
166F044 DOOR INST
166F286 DOOR INSTL. LWR.
EQUIP COMPT
XF 233.50
XF 243.
XF 273
℄ FWD LIFT POINT
166F261
℄ AFT LIFT POINT
166F261
EQUIPMENT COMPT DOORS
LATERAL FORCE ± 3000LB
ZF 51.50
P_x = ± 2600 LB
ZF 53.47
P_z = ± 4925 LB
F171
-STATIC TUBE HEATED
166K051 FEEDTHRU INSTL
BATTERY DISCONNECT
RH SIDE ONLY
166F249 BULKHEAD FUS STA 233.500
℄ .500/.505 DIA INDEX HOLE
166F182 DOOR INSTL-ENGINE START
166K035
℄ 1.062

D

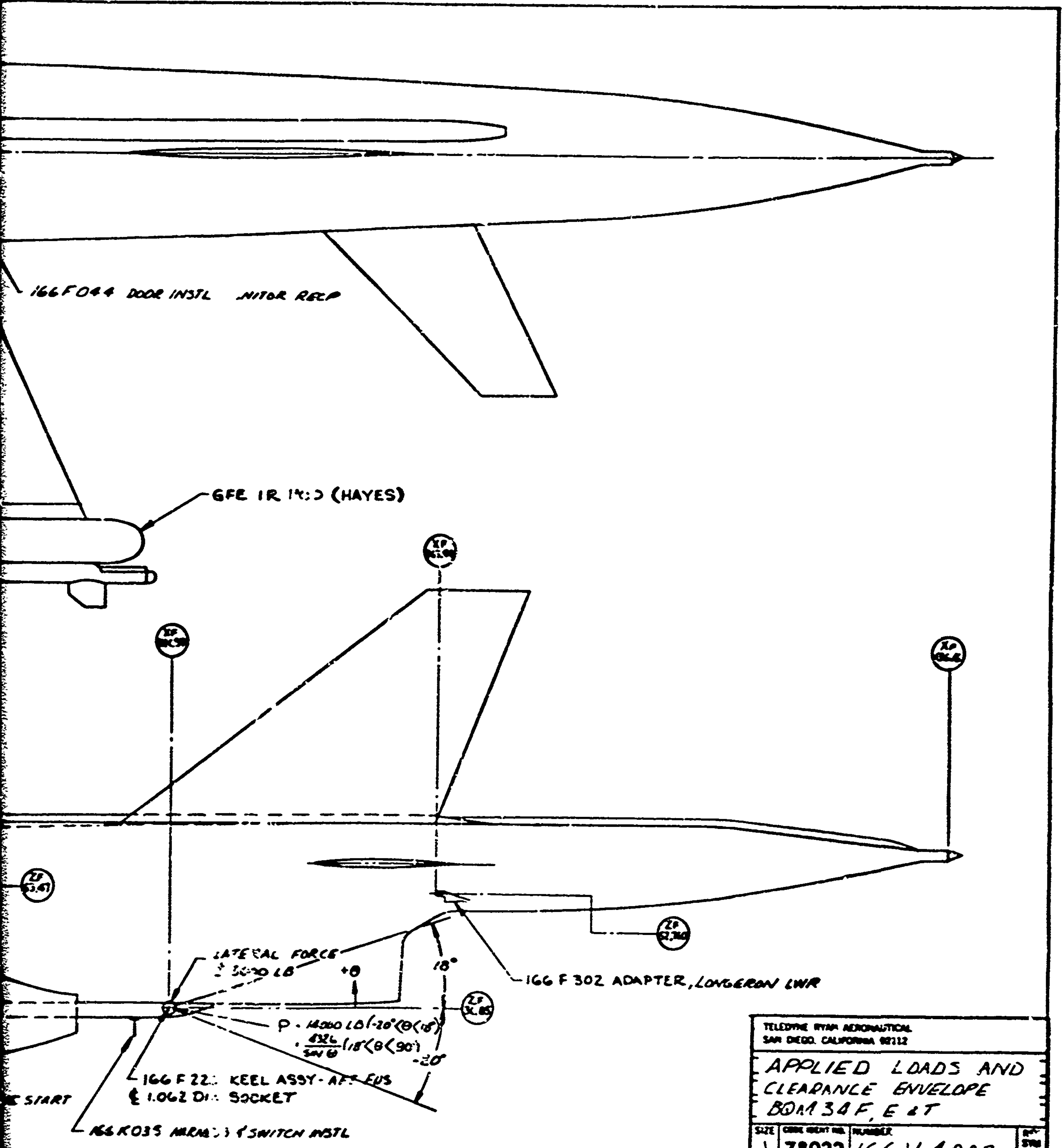


Figure 2-2. General Arrangement, BQM-34F, E, and T

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2.2 AERODYNAMICS

The BQM-34A configuration described in Paragraph 2.1 specifies the addition of a drag increment for 11-inch diameter CIR wingtip pods. This increment was estimated by using the methods of Reference 1 to determine subsonic zero lift drag. Pod induced drag was derived using data from References 1 and 2. Interference drag was derived from Reference 3 and unpublished data.

The resulting drag coefficient increment is 0.0132 for two pods and is valid for all lift coefficients and Mach numbers consistent with launch calculations.

All aerodynamic data based on published information for the configurations described were supplied for six-degree-of-freedom simulation studies (Reference 4). Results are presented in Paragraph 2.6.

2.3 PROPULSION

The TCAE J69-T-29 installed engine performance for the BQM-34A and the TCAE YJ69-T-406 installed engine performance for the BQM-34F were estimated for minimum and maximum thrust conditions. The minimum thrust operational conditions were specified at an altitude of 5,000 feet, ambient temperature of 105°F. and an engine speed of 100 percent. The gross thrust, fuel flow rate, and ram drag for minimum thrust conditions are presented in Figures 2-3 and 2-4 for the BQM-34A and BQM-34F, respectively. Note that the gross thrust vector acts along the jet axis which is inclined downward with respect to the aircraft axis. This corresponds to 15 degrees for the BQM-34A and 8-1/3 degrees for the BQM-34F. The ram drag vector acts along the flight path. This applies to Figures 2-3 through 2-6.

The maximum engine thrusts would occur at sea level -20°F ambient temperature and 100 percent engine speed conditions. The gross thrust and ram drag for maximum thrust conditions are presented in Figures 2-5 and 2-6 for the BQM-34A and BQM-34F, respectively.

The variation of engine speed (rpm) with ambient pressure and temperature was estimated for a constant static thrust of 1,030 pounds for the BQM-34A and 1,005 pounds for the BQM-34F. The results are presented in Figures 2-7 and 2-8 for the BQM-34A and BQM-34F, respectively. All catapult launches will be made at the rpm corresponding to the static engine thrust levels used in the dynamic analyses. These rpm values are determined from Figures 2-7 and 2-8. As an example for the use of both

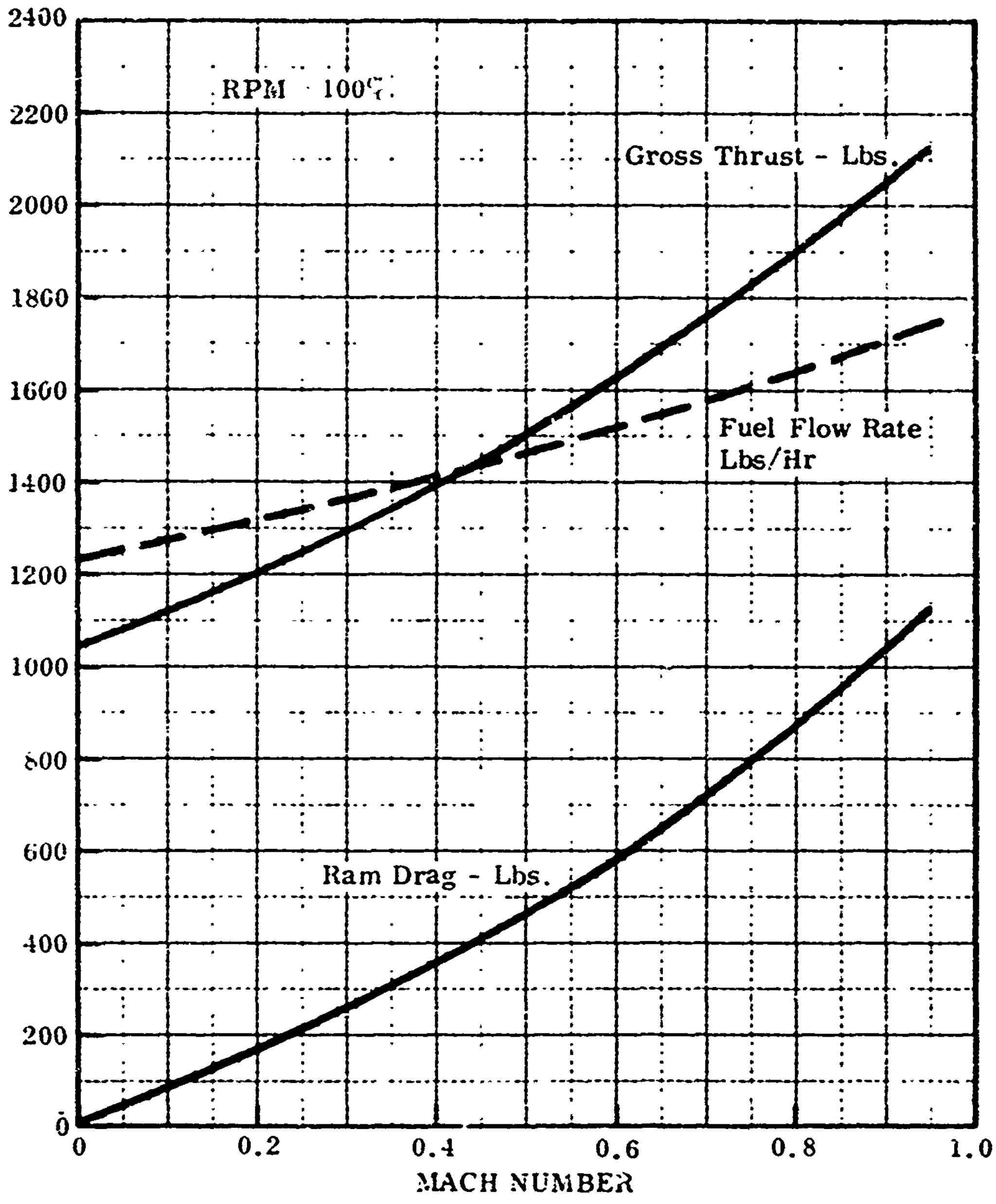


Figure 2-3. BQM-34A J69-T-69 Engine Gross Thrust Ram Drag and Fuel Flow Rate at 5,000 Feet and Ambient Temperature of 105 Degree F.

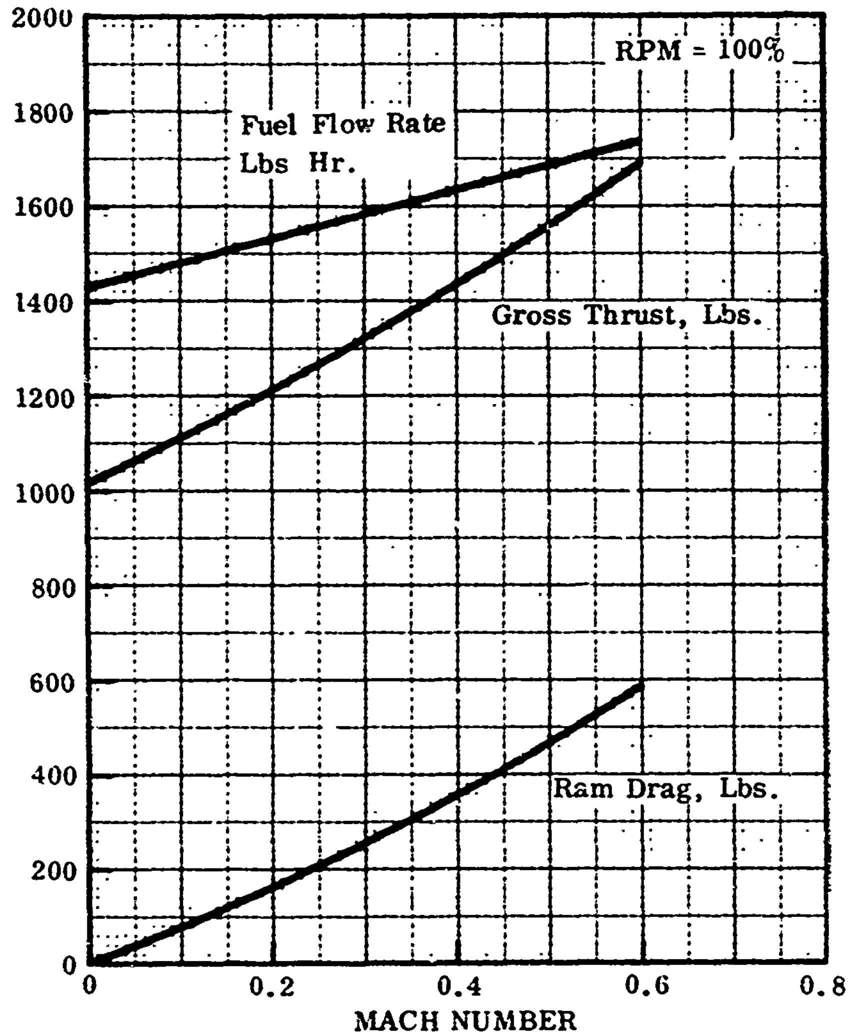


Figure 2-4. BQM-34F YJ69-T-406 Engine Gross Thrust, Ram Drag and Fuel Flow Rate at 5,000 Feet and Ambient Temperature of 105 Degree F.

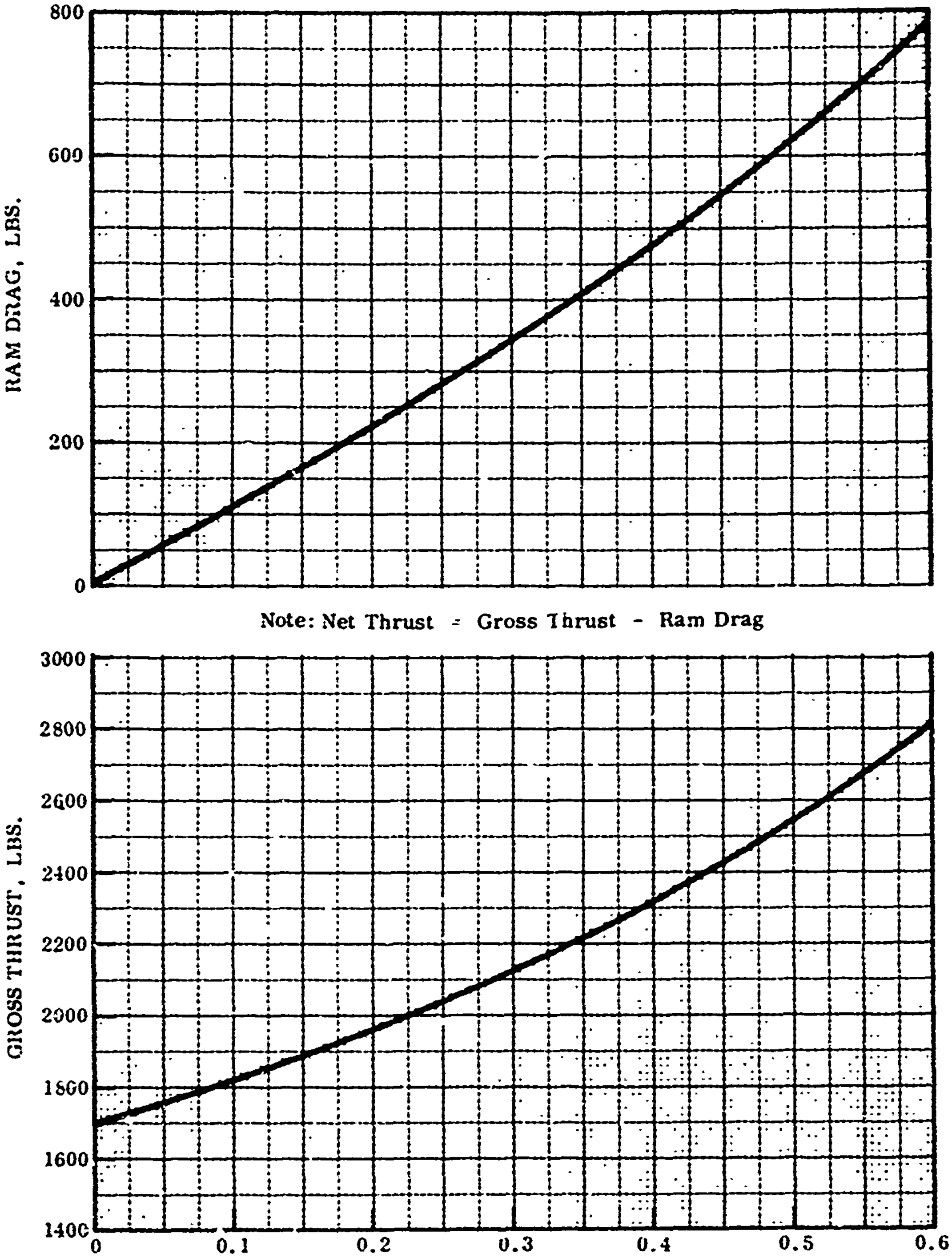


Figure 2-5. BQM-34A J69-T-29 Engine, Gross Thrust and Ram Drag, 100 Percent Rpm, Sea Level, Ambient Temperature, -20 Degree F.

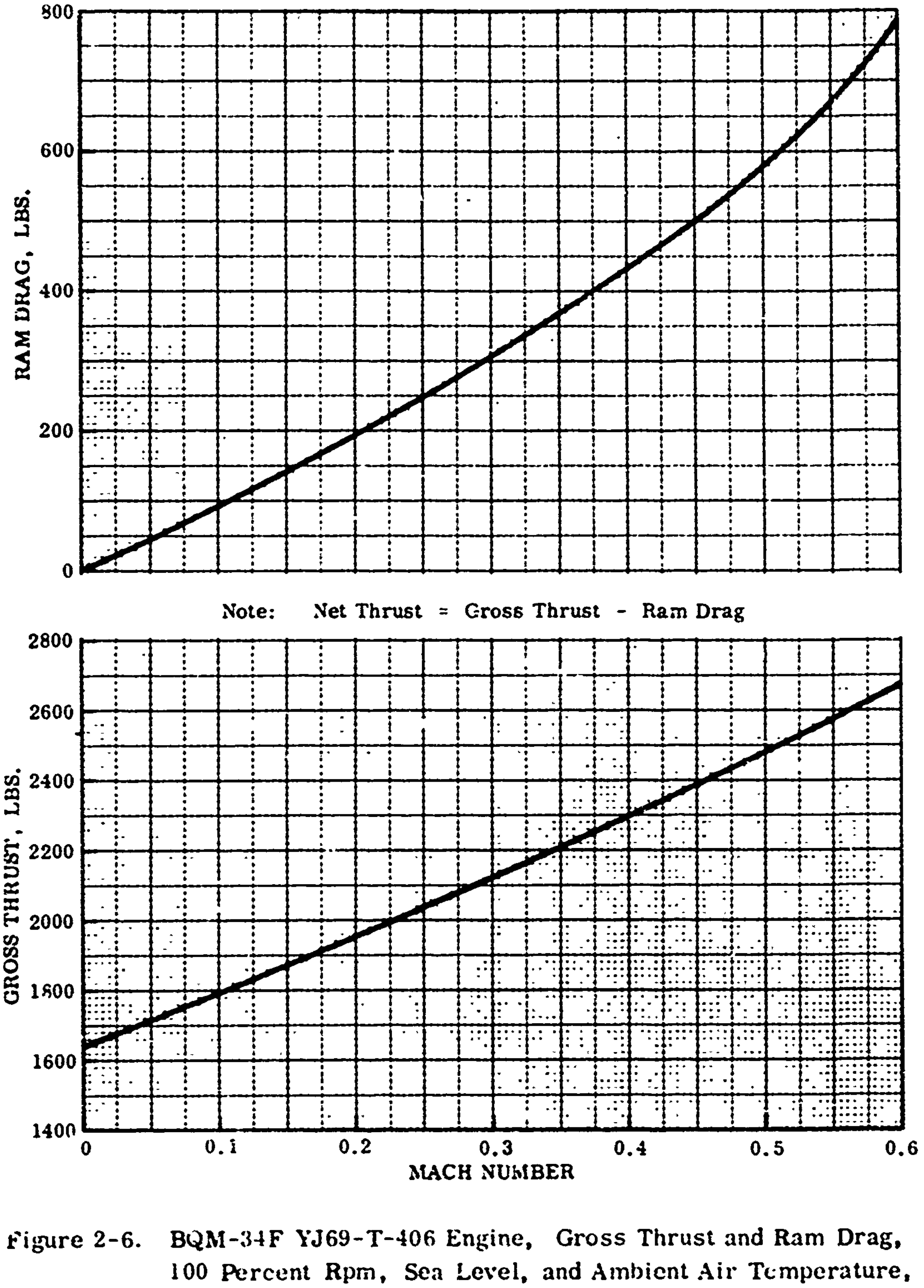


Figure 2-6. BQM-34F YJ69-T-406 Engine, Gross Thrust and Ram Drag, 100 Percent Rpm, Sea Level, and Ambient Air Temperature, -20 Degree F.

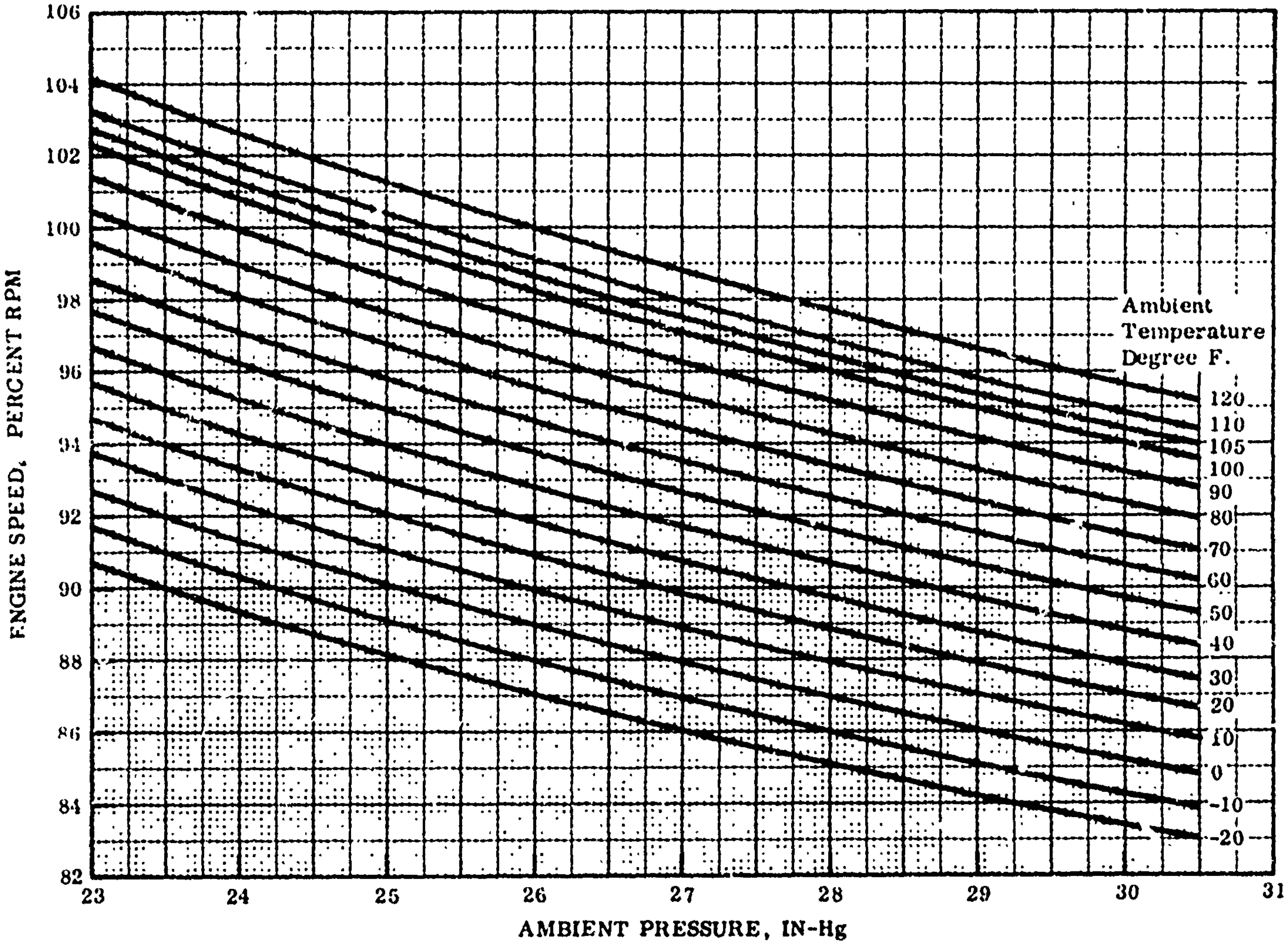


Figure 2-7. BQM-34A J69-T-29 Engine, Variation of Engine Speed with Ambient Pressure and Temperature for a Constant Thrust of 1030 Pounds at Mach No. = 0

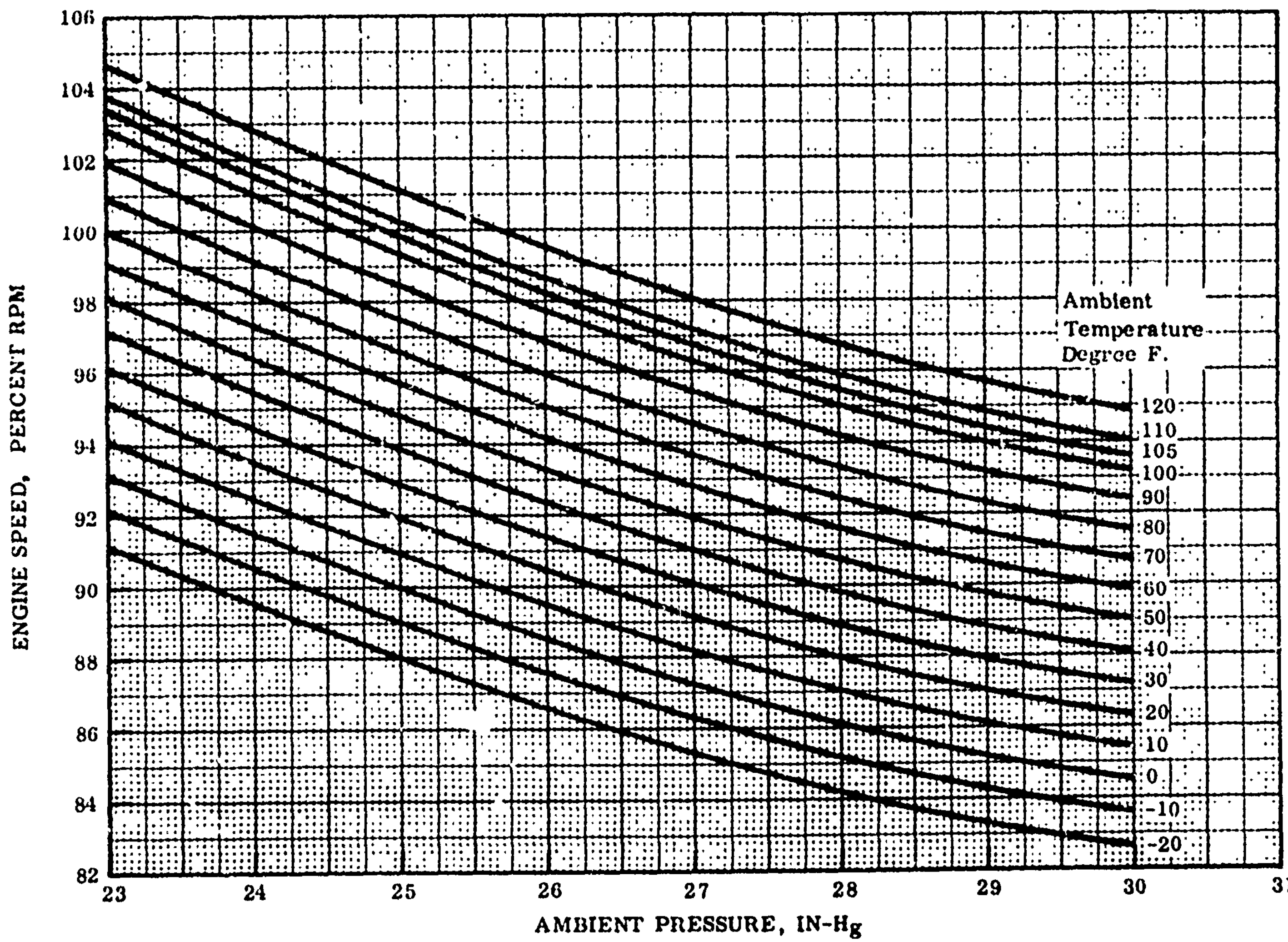


Figure 2-8. BQM-34F YJ69-T-406 Engine, Variation of Engine Speed with Ambient Pressure and Temperature for a Constant Thrust of 1005 Pounds at Mach No. = 0

Figures 2-7 and 2-8 for a catapult launch of a BQM-34A at an ambient pressure of 25.46 inches of mercury and an ambient air temperature of 40°F, the following procedure applies. From Figure 2-7, the intersection of the aforementioned pressure and temperature read an rpm of 93.4 percent. This corresponds to a static engine thrust level of 1,030 pounds.

Provisions must be made to ensure that the vehicles are protected against foreign object damage (FOD) while on the catapult during engine start and run-up, and during the ground launch sequences. In the past, such protection has been provided by a screened bellmouth auxiliary inlet for ground run-up. In addition, a retractable sugar scoop auxiliary inlet has been used on ground launchers for engine start and run-up to launch rpms. These auxiliary inlets originally were utilized to eliminate a mild surge condition in the 80 to 90 percent rpm range for the prototype BQM-34A vehicles. From recent experience and deliberate investigation, it appears that conditions causing the surge in the prototype vehicles no longer exist. Consequently, the use of either auxiliary bellmouth in conjunction with the catapult is not required. Protection against FOD still is a requirement unless it can be proven such protection is unnecessary.

2.4 MASS PROPERTIES

2.4.1 Basic BQM-34A Design Data

Original design conditions for the BQM-34A are presented below:

a. Design Gross Weight = 2,500 Pounds

b. Forward Center-of-Gravity Limit = 3% MAC (X_F 86.3)

c. Aft Center-of-Gravity Limit = 29.3% MAC (X_F 95.08)

d. Horizontal Reference Plane = X_F 0.0

e. Vertical Reference Plane = Z_F 0.0

f. Lateral Reference Plane = 100 Inches to Left of Y_F 0.0

2.4.1.1 BQM-34A Horizontal Center-of-Gravity Envelope

The forward center-of-gravity limit is a structural limitation based on a design gross weight of 2,500 pounds and an ultimate load factor of 6.65. This limit is used for the most forward center-of-gravity limitation on the center-of-gravity envelope curve (Figure 2-9).

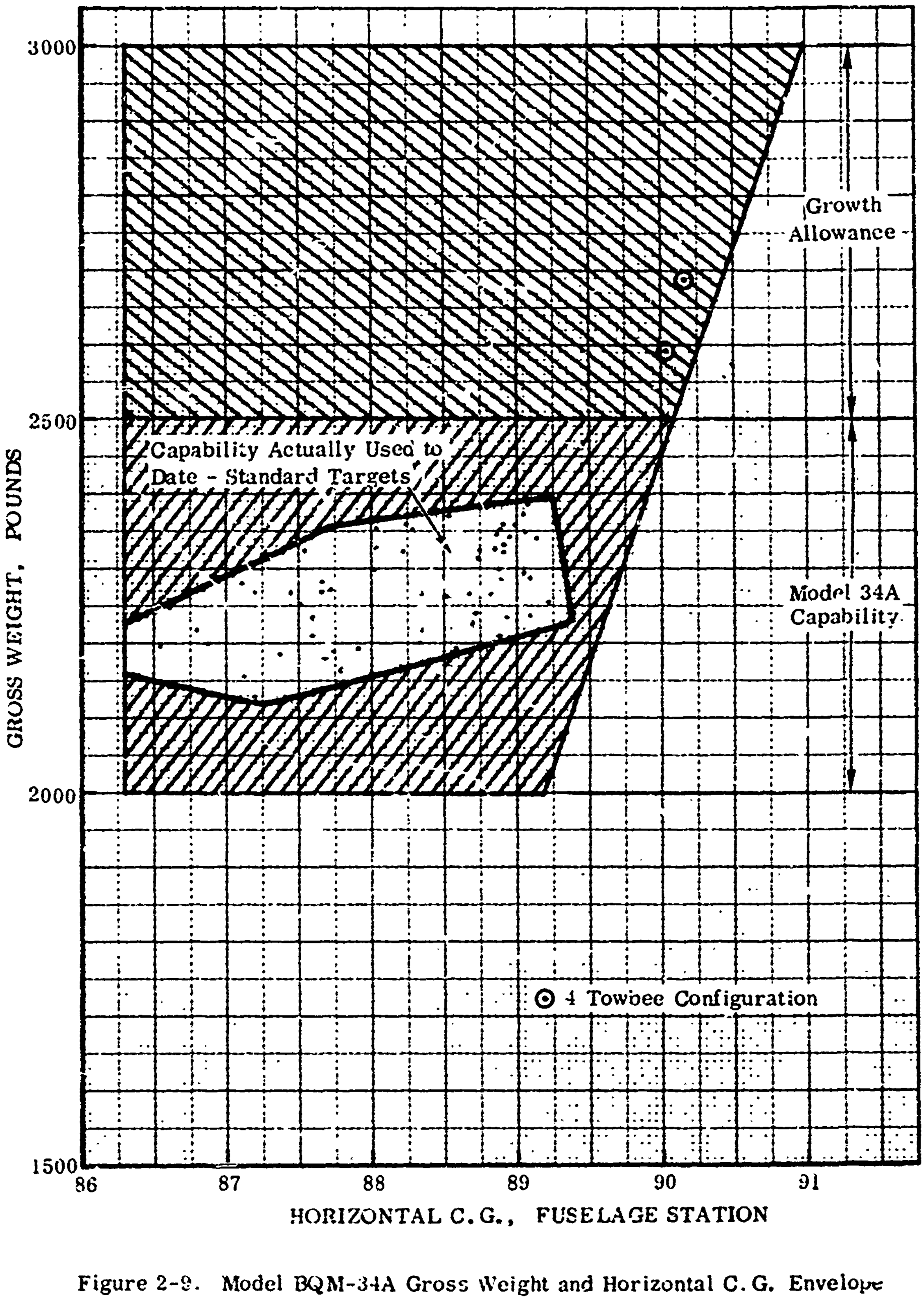


Figure 2-9. Model BQM-34A Gross Weight and Horizontal C.G. Envelope

The aft center of gravity is an aerodynamic limit not to be exceeded during flight conditions. Due to the design features of the BQM-34A, the most aft center of gravity during flight occurs when 10 percent of the fuel is remaining. These data are used to derive the most aft center-of-gravity limitation on the center-of-gravity envelope curve of Figure 2-9 for gross weights with full fuel including growth to 3,000 pounds and minimum weight of 2,000 pounds.

Actual horizontal center-of-gravity data for several standard BQM-34A configurations are also shown in Figure 2-9.

2.4.1.2 BQM-34A Vertical Center-of-Gravity Envelope

There are no aerodynamic or structural limitations established for vertical center-of-gravity locations of the BQM-34A. The only existing limitations are based on maximum and minimum adjustments in RATO alignment hardware. These limitations were compared with actual vertical center-of-gravity data for the BQM-34A configurations and were found to be adequate and reasonable limits in all cases analyzed.

Actual vertical center-of-gravity data for several standard target configurations and two experimental configurations are also shown in Figure 2-10.

2.4.2 Basic BQM-34F Design Data

Original design conditions for the BQM-34F are presented below:

a. Design Gross Weight = 2,500 Pounds

b. Forward Center-of-Gravity Limit = 15% MAC (X_F 259.04)

c. Aft Center-of-Gravity Limit Without Wingtip Stores = 27.5% MAC (X_F 264.92)

d. Aft Center-of-Gravity Limit With Wingtip Stores (IR Pods) = 31.5% MAC (X_F 266.80)

The BQM-34F can also be flown with or without the external fuel tank and each case is treated as a separate configuration due to weight and center-of-gravity differences.

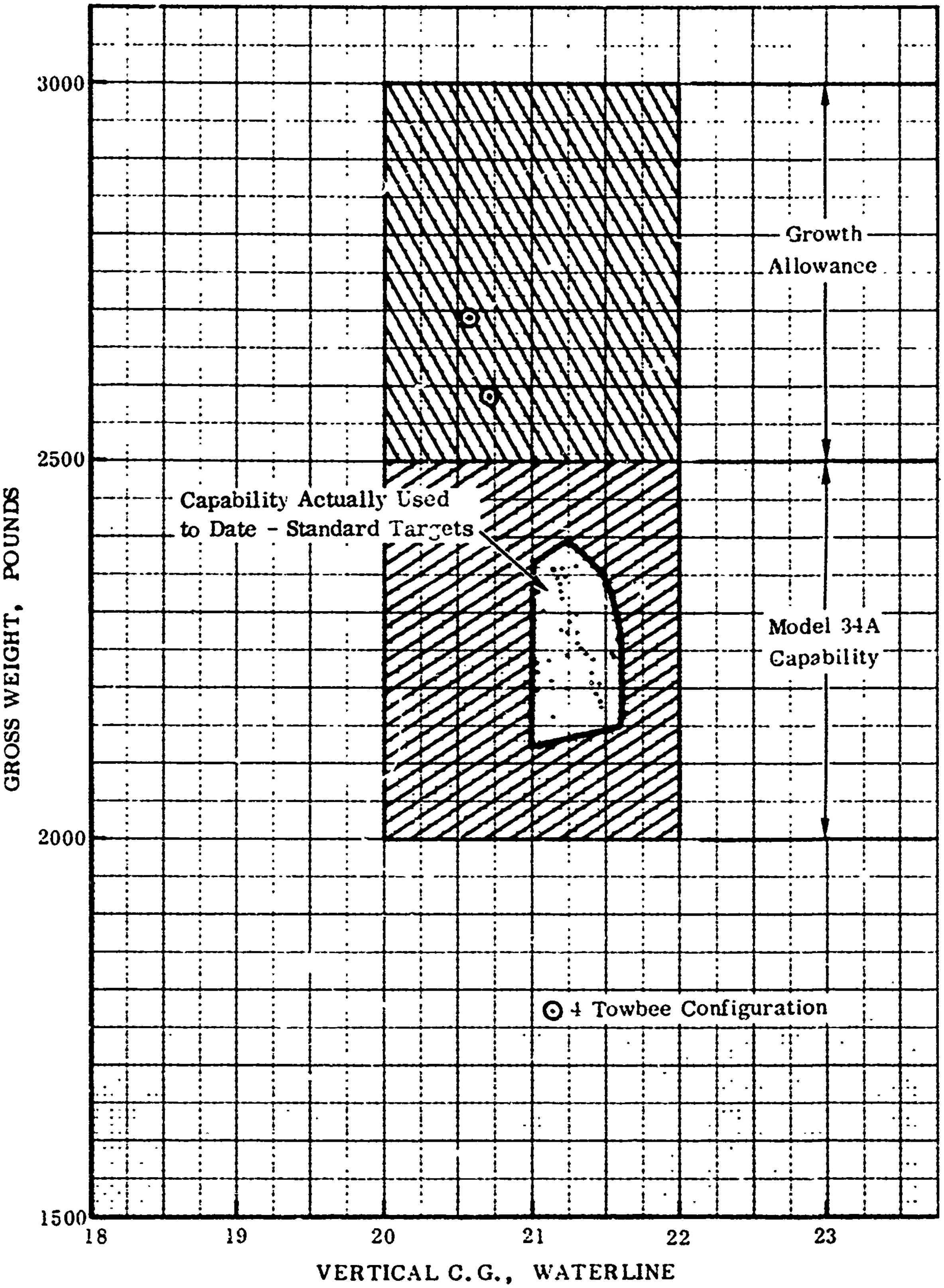


Figure 2-10. Model BQM-34A Gross Weight and Vertical C.G. Envelope

2.4.2.1 BQM-34F, Horizontal Center-of-Gravity Envelope, Internal Fuel Only

The forward center-of-gravity limit is used as the most forward center-of-gravity limitation on the center-of-gravity envelope curve of Figure 2-11.

The aft center-of-gravity limit is with IR pods on and the most aft center-of-gravity condition for the BQM-34F is also at zero fuel weight. These data are used to derive the most aft center-of-gravity limitation on the center-of-gravity envelope curve for a gross weight range of 1,700 pounds to 2,500 pounds (Figure 2-11).

The BQM-34F is a relatively new configuration and actual center-of-gravity data has been limited. However, the data available are also shown in the figure.

2.4.2.2 BQM-34F Vertical Center-of-Gravity Envelope, Internal Fuel Only

Maximum and minimum adjustments in RATO alignment hardware provide the only specified limitations on the vertical center of gravity for the BQM-34F. The limitations shown, however, are based on actual data.

Actual vertical center-of-gravity data for the BQM-34F are shown on the envelope curve of Figure 2-12.

2.4.2.3 Model BQM-34F Horizontal and Vertical Center-of-Gravity Envelopes With Internal and External Fuel

Data for the BQM-34F horizontal center-of-gravity envelope are derived on the same basis as used on the clean configuration, except the gross weight range used is from 2,100 pounds to 3,000 pounds due to the heavier weight. These are shown in Figures 2-13. Data for the vertical center-of-gravity envelope are shown in Figure 2-14.

2.5 STRUCTURES

This paragraph presents structural information concerning the BQM-34A and BQM-34F airframes which must be considered in the design and development of a catapult launcher for these target vehicles. Aerodynamic loads developed by the vehicles are presented as a function of a number of variables, including airspeed, side winds and attitude. The maximum loads that may be applied to the airframes at specified hard

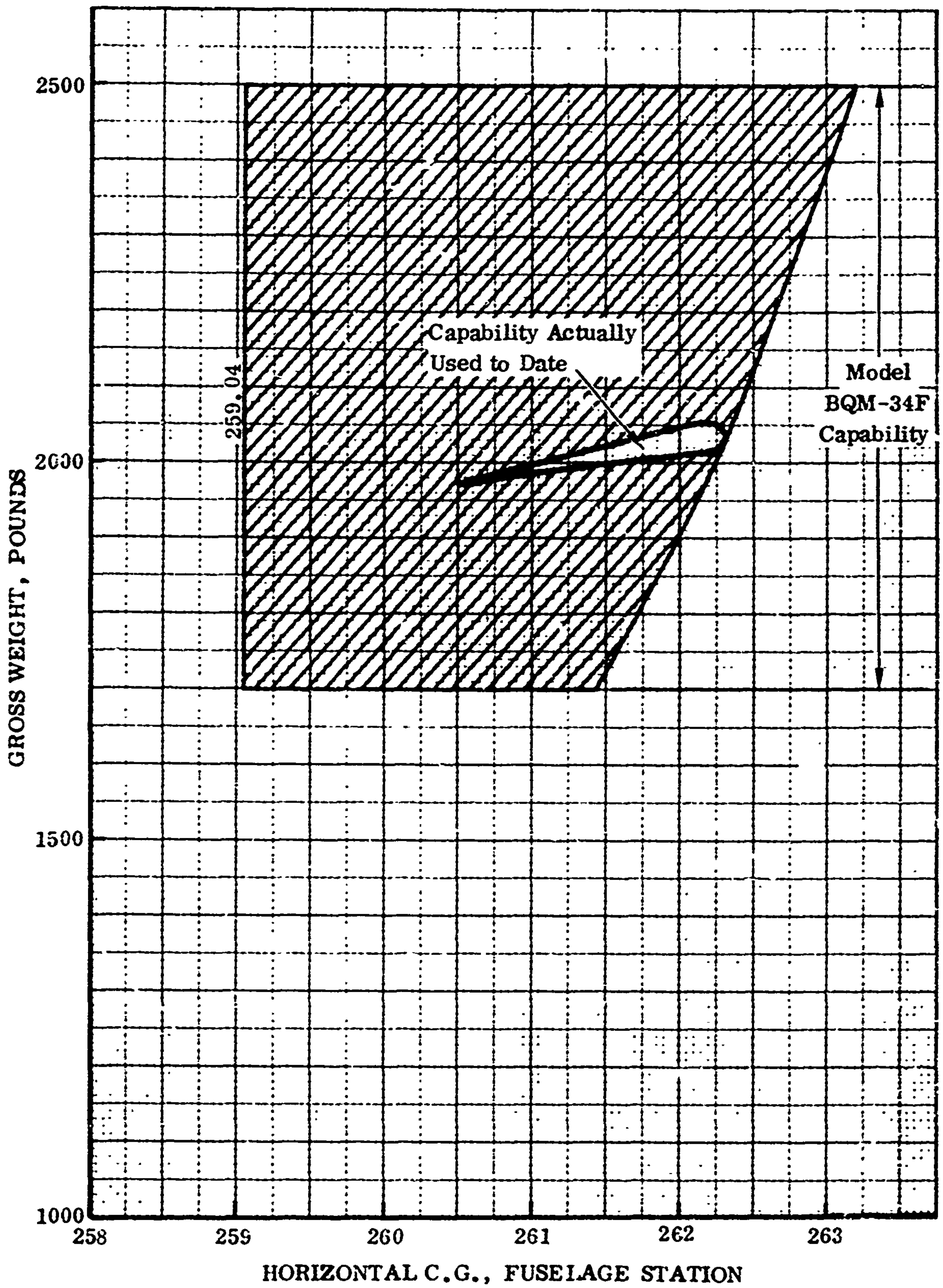


Figure 2-11. Model BQM-34F Gross Weight and Horizontal C.G. Envelope for Internal Fuel Only

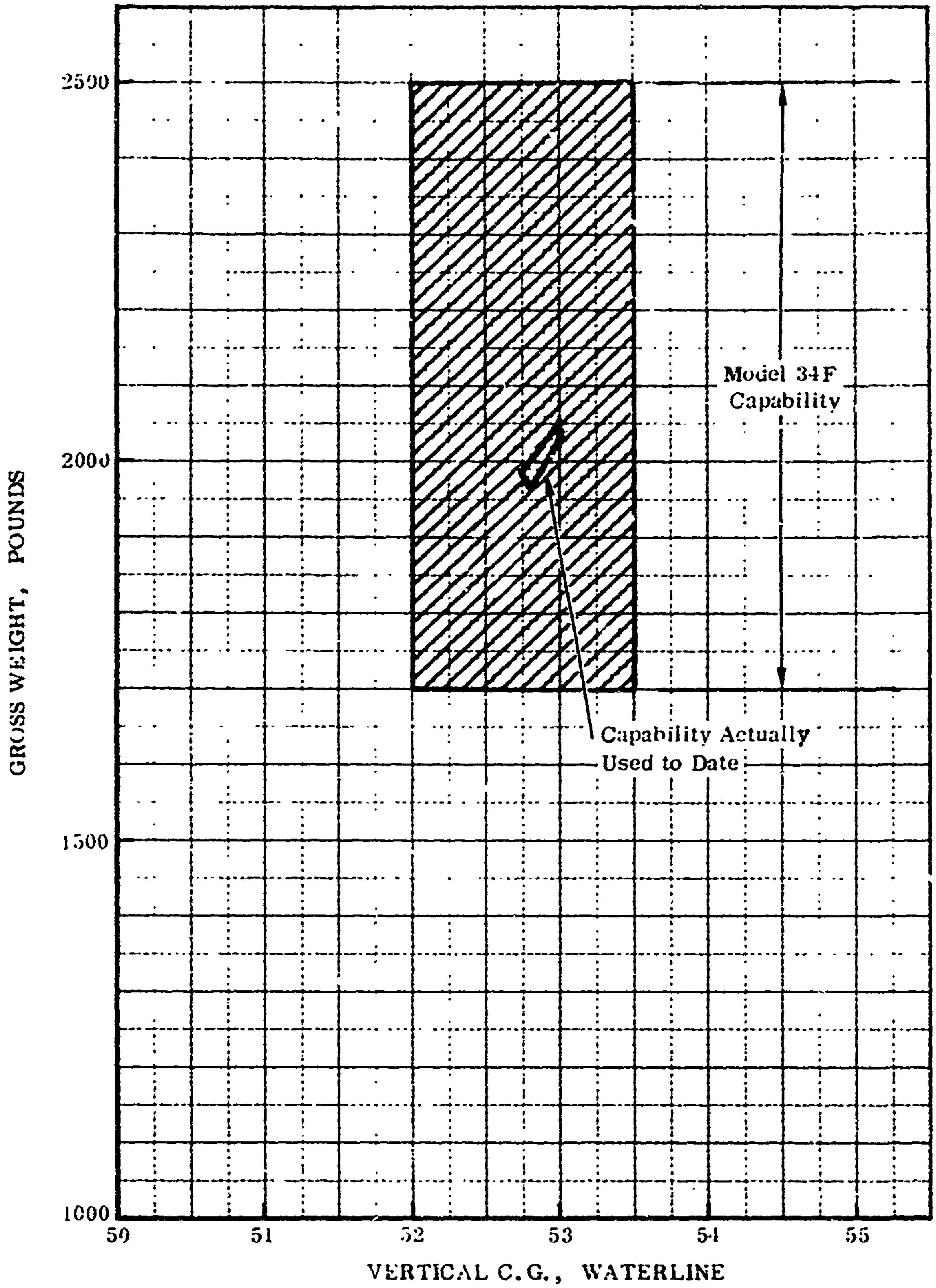


Figure 2-12. Model BQM-34F Gross Weight and Vertical C.G. Envelope for Internal Fuel Only

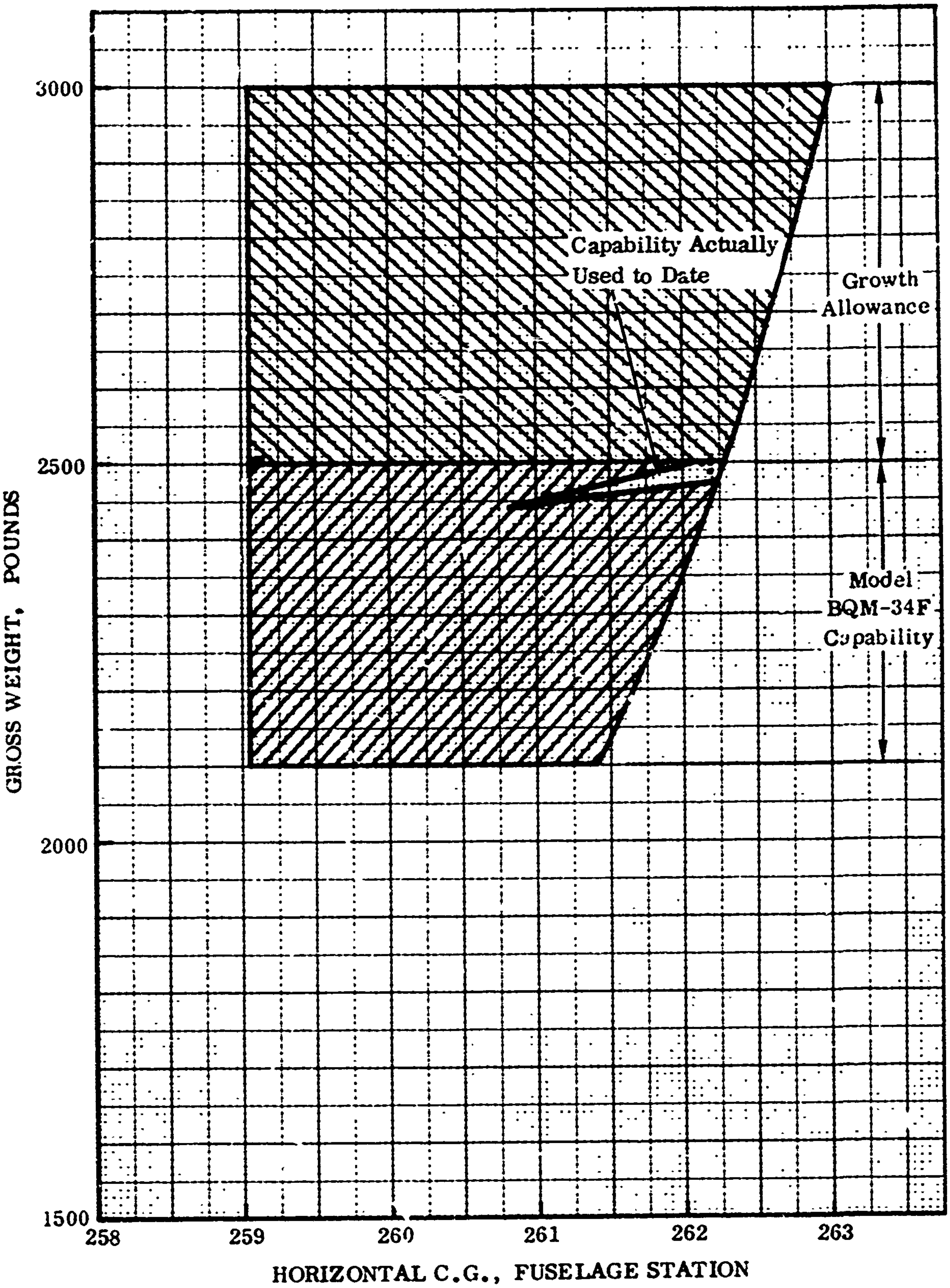


Figure 2-13. Model BQM-34F Gross Weight and Horizontal C.G. Envelope for Internal and External Fuel

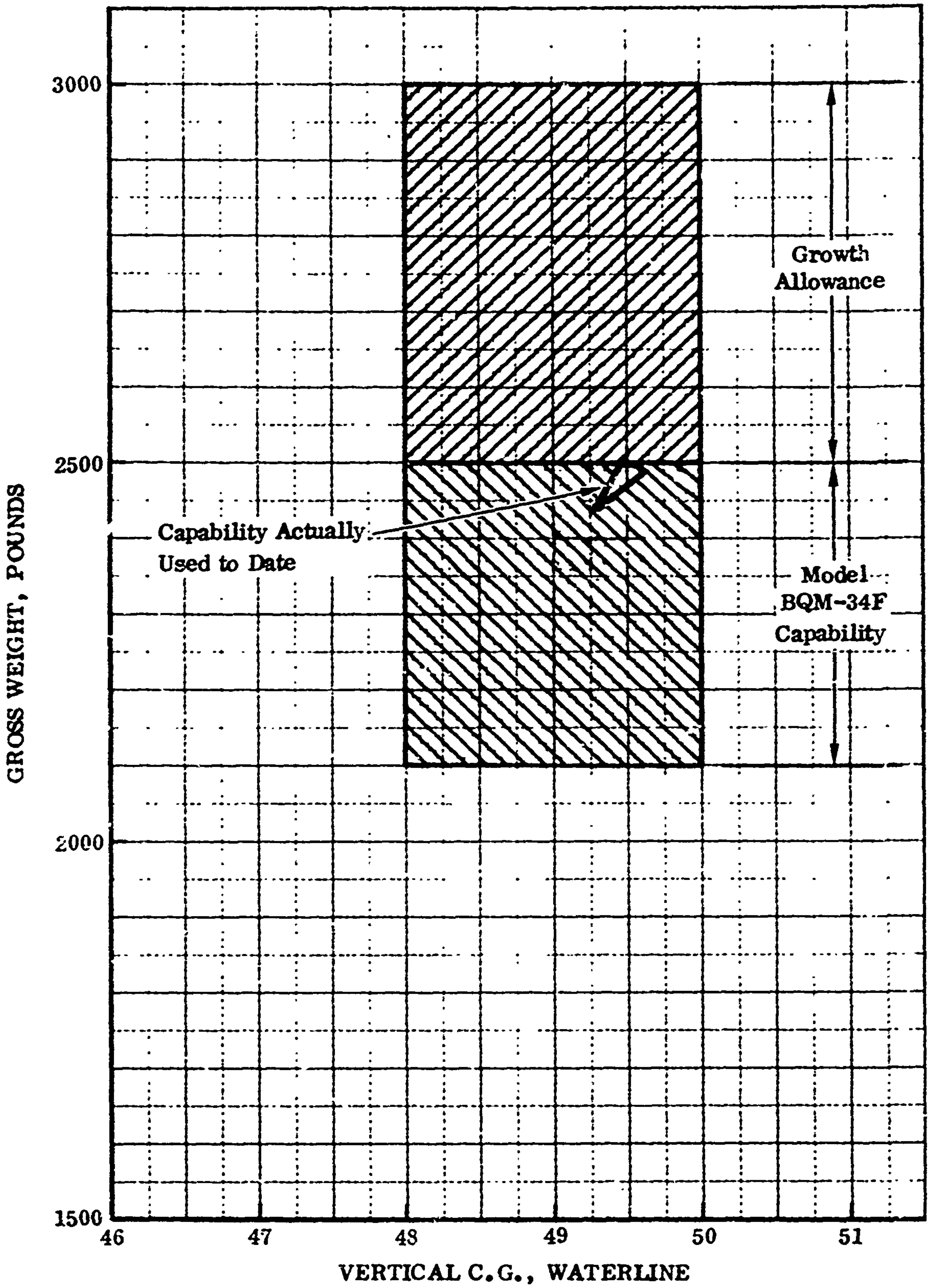


Figure 2-14. Model BQM-34F Gross Weight and Vertical C.G. Envelope for Internal and External Fuel

points are presented as are the maximum accelerations that may be imposed. The effects of jet engine thrust is also discussed.

Figure 2-15 shows the sign convention used for presenting loads and accelerations. Any deviations are clearly noted.

2.5.1 Aerodynamic and Engine Thrust Forces

Aerodynamic forces on the targets and the forces generated by jet engine thrust are presented in Figures 2-16 through 2-21. In Figures 2-16 and 2-17, the longitudinal aerodynamic forces are shown for the BQM-34A and BQM-34F, respectively. The forces show the effects of the different pitch angles and two elevator positions as a function of airspeed. Linear interpolation may be used to determine aerodynamic forces for target pitch angles and elevator positions other than those shown. The airspeed may be considered the sum of the dolly ground speed and head or tail winds. As an example, consider a BQM-34A catapult launch at the following conditions:

a. Pressure altitude = 5,000 feet

b. Temperature = 105°F

c. Launch ground velocity required with 15-knot (25-fps) tail wind = 465 fps

d. Elevators 100 percent trailing edge up

e. Target pitch angle of 10 degrees

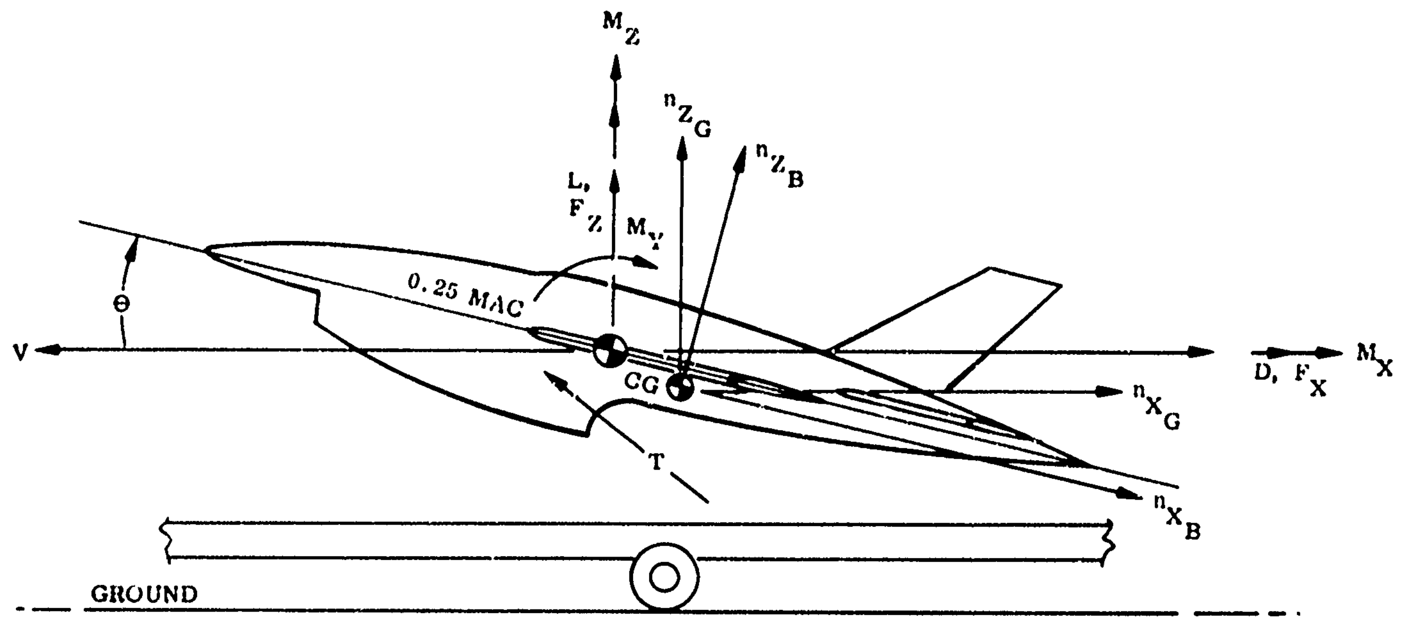
The airspeed is 440 fps which converts to 247 knots equivalent airspeed (KEAS). The following aerodynamic forces are obtained from Figure 2-16:

a. L = 4,250 pounds vertical to rails

b. D = 2,050 pounds parallel to rails

c. M_Y = 39,300 inch-pounds

The lateral-directional aerodynamic forces due to a 15-knot side wind are shown in Figures 2-18 and 2-19. Figures 2-20 and 2-21 present forces due to net engine thrust levels of 2,000 pounds.



NOTES:

1. All quantities shown are positive. Positive forces, accelerations and load factors are up, aft and left.
2. Use left hand rule for moments M_x and M_z
3. Lateral load factor (n_y) and side force (L_y) are positive to left.
4. Positive accelerations produce positive load factors.
5. BQM-34A (124) 25% MAC - FS 93.646, BLO, WL 20
   BQM-34F (166) 25% MAC - FS 263.74, BLO, WL 57
6. Subscript "G" - ground axes, parallel and normal to launch rails.
   Subscript "B" - RPV body axes.

Figure 2-15. Sign Convention for Loads Analysis

NOTES:

1) ▬ ▬ ▬ ▬ ELEVATORS AT ZERO;
   ▬▬▬▬ FULL T.E. UP ELEVATORS

2) LOAD REF. POINT IS 25% MAC, Z_F 20

3) LOADS ARE IN GROUND AXES; LIMIT LOADS

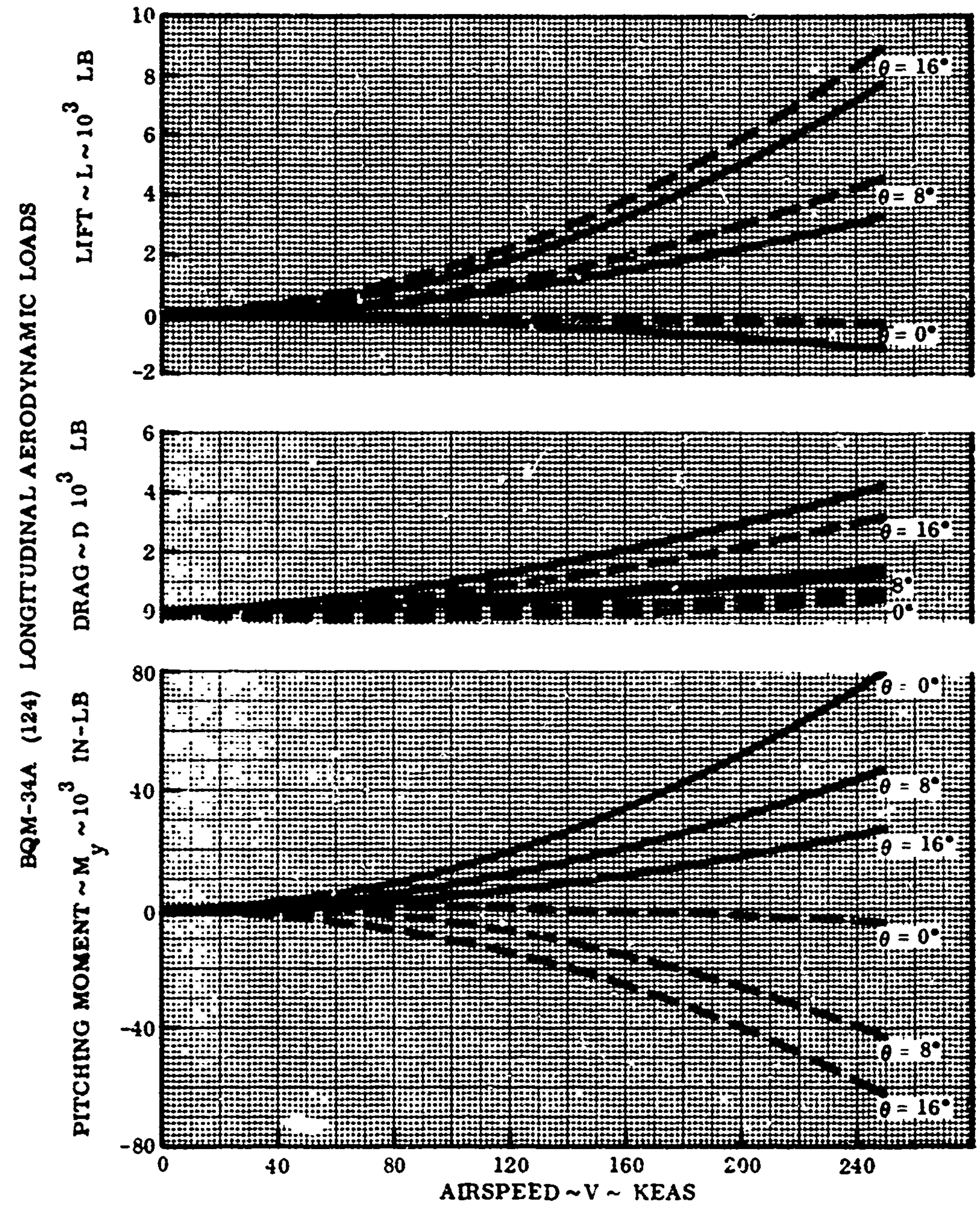


Figure 2-16. BQM-34A (124) Longitudinal Aerodynamic Loads vs. Airspeed

NOTES:

1) — — ELEVATORS AT ZERO;
——— FULL T.E. UP ELEVATORS
2) LOAD REF. POINT IS 25% MAC, Z_F 57
3) LOADS ARE IN BODY AXES
4) LIMIT LOADS

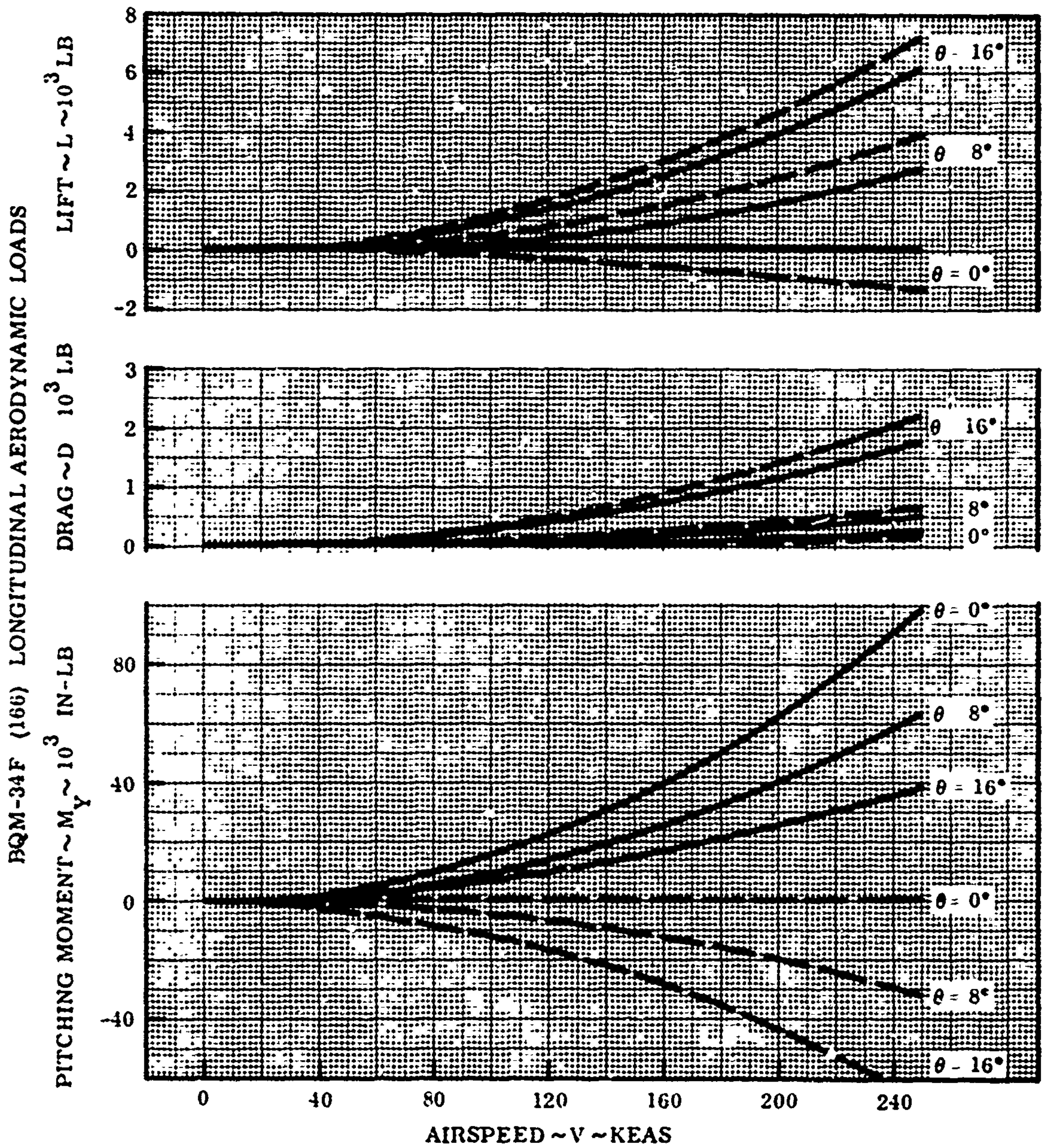


Figure 2-17. BQM-34F (166) Longitudinal Aerodynamic Loads vs. Airspeed

NOTES:

1) SIDE WINDS OF 15 KTAS
2) LOAD REFERENCE POINT IS 25% MAC, Z_F 20
3) LOADS ARE IN GROUND AXES
4) LIMIT LOADS
5) USE FOR ALL TARGET PITCH ANGLES ON LAUNCHER

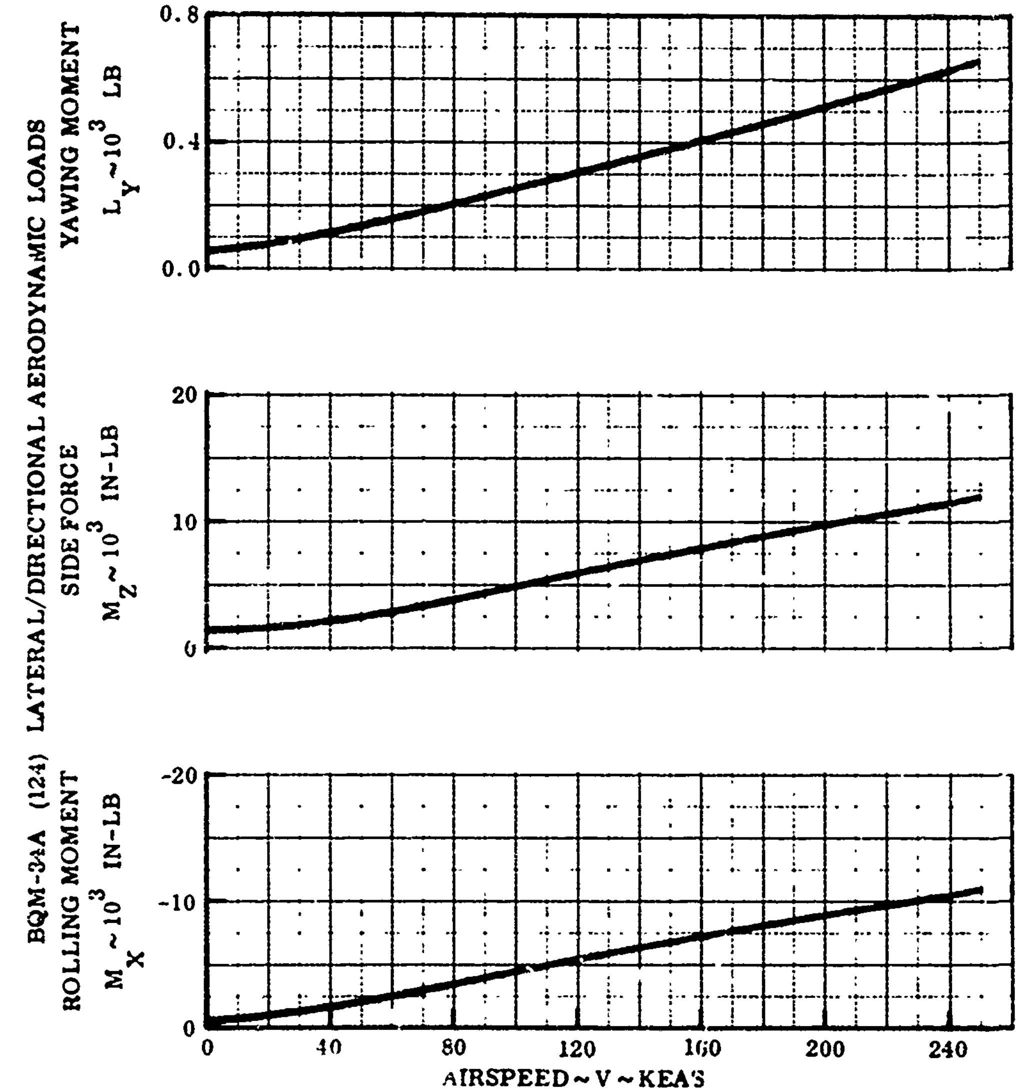


Figure 2-18. BQM-34A (124) Lateral/Directional Aerodynamic Loads for Side Ground Winds

NOTES:

1) SIDE WIND OF 15 KTAS
2) LOAD REFERENCE POINT IS 25% MAC, Z_F 57
3) LOADS ARE IN GROUND AXES
4) LIMIT LOADS
5) USE FOR ALL TARGET PITCH ANGLES ON LAUNCHER

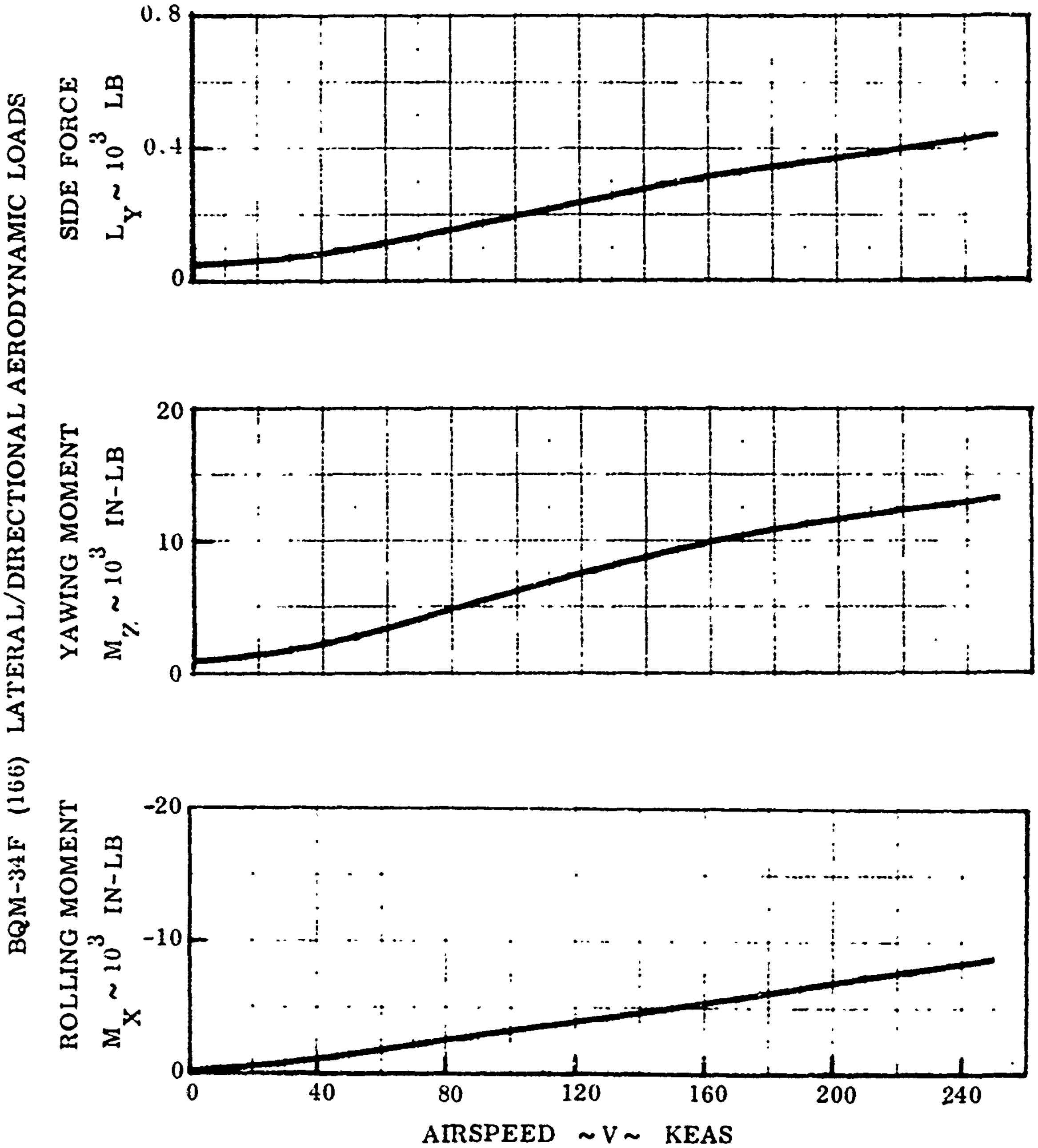


Figure 2-19. BQM-34F (166) Lateral/Directional Aerodynamic Loads for Side Ground Winds

NOTES:

1) LOAD REFERENCE POINT IS 25% MAC, Z_F 20; GROUND AXES
2) LOADS ARE LIMIT
3) RATIO DIRECTLY TO OBTAIN FORCES FOR VALUES OF NET THRUST OTHER THAN 2000 LB.

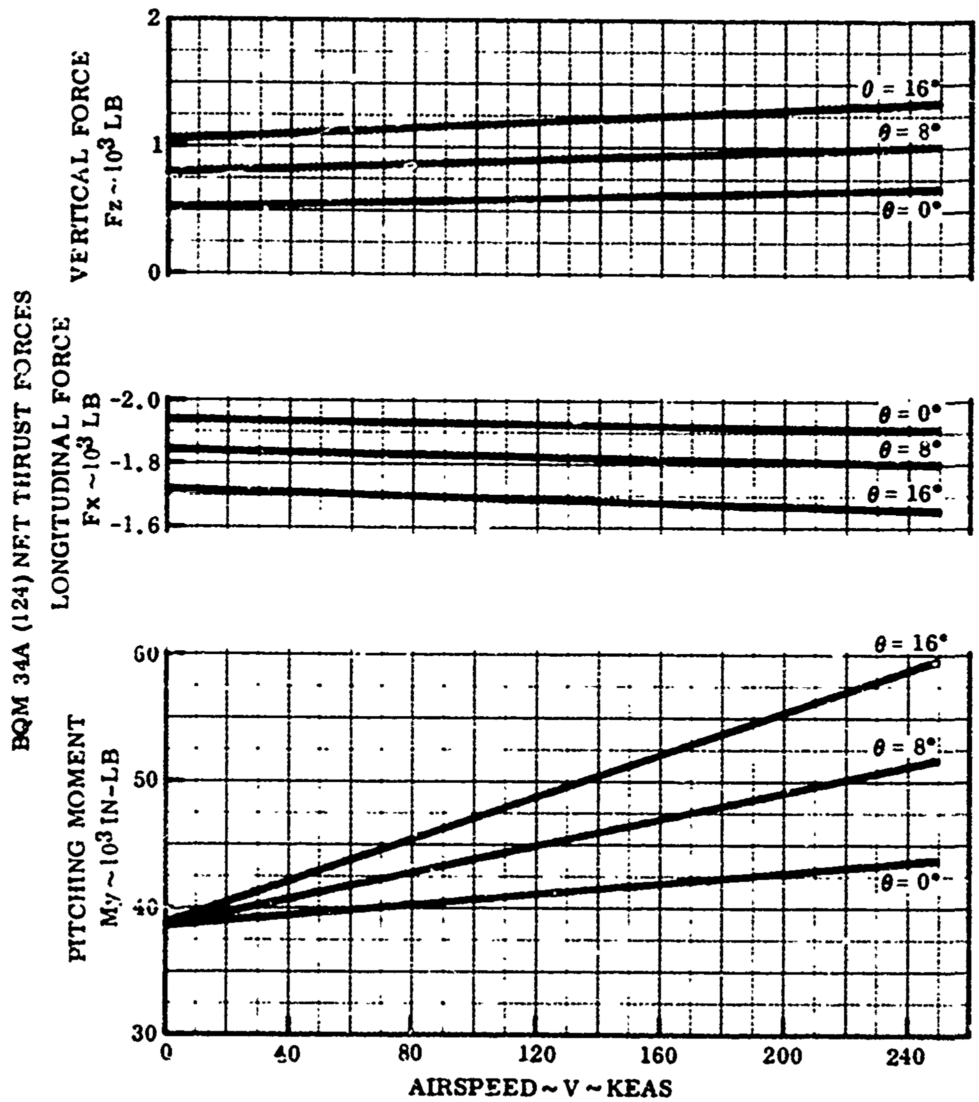


Figure 2-20. BQM-34A (124) Forces vs. Airspeed for 2,000-Pounds Net Thrust

NOTES:

1) LOAD REFERENCE POINT IS 25% MAC, Z_F 57; GROUND AXES
2) LOADS ARE LIMIT
3) RATIO DIRECTLY TO OBTAIN FORCES FOR VALUES OF NET THRUST OTHER THAN 2000 LB.

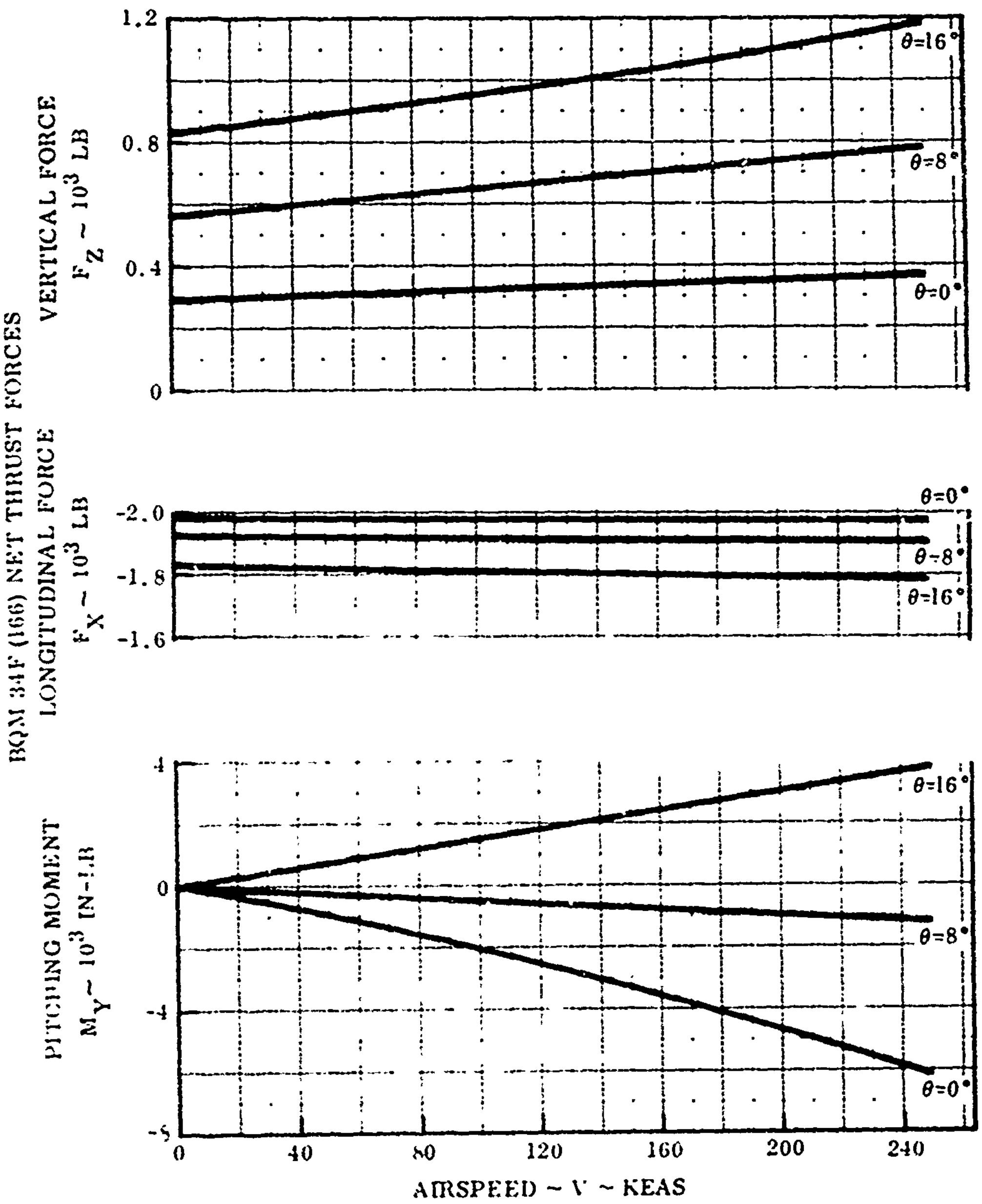


Figure 2-21. BQM-34F (166) Forces vs. Airspeed for 2,000-Pound Net Thrust

Refer to Paragraph 2.3 for engine thrust data for various environmental conditions. The forces of Figures 2-20 and 2-21 may be directly ratioed to any desired value of net engine thrust. All of the forces and moments of Figures 2-16 through 2-21 are limit loads and include no safety factors.

2.5.2 Airframes Structural Limitations

Existing hard points and the airframe structure of the BQM-34A and BQM-34F vehicles were evaluated to determine allowable inertia load factors and interface loads during a catapult launch. It is assumed that no structural modifications are incorporated and that interface loads will be applied to existing hard points. Normal fuel pressurization at launch is considered. Inertia fuel pressure computations are based on the use of JP-5 fuel at standard conditions.

On the BQM-34A, the forward and aft fuel tank bulkheads are sensitive to fuel pressure resulting from longitudinal acceleration. The vertical members on the aft bulkhead at X_F 36.0 are critical under bending stress due to forward acting pressure loads. On the BQM-34F, the engine inlet duct is critical under collapsing external pressure due to fuel inertia loads combined with internal negative pressure due to airflow with the engine running. The forward end of the duct is critical from fuel pressures due to forward acting fuel pressure loads.

The maximum allowable limit load factors for the BQM-34A and BQM-34F targets are presented as envelopes in Figures 2-22 through 2-25. These values are the maximum allowable limit load factors to which the vehicles may be subjected. These limit values are consistent with an ultimate factor of safety of 1.50 between limit and ultimate. It should be noted that the load factor envelopes of Figures 2-22 through 2-25 are presented in the target body axis system.

During the catapult launch, contributions to the loads and accelerations experienced by the targets can be expected from the applied acceleration forces, engine thrust forces, aerodynamic forces due to forward airspeed and ground winds, and undulations in the tracks or rails of the catapult launcher. The most critical combination of these effects, and perhaps others, must not exceed the limit load factor envelopes of Figures 2-22 through 2-25. Accelerations calculated in the catapult launcher axis system must be transformed to the target body-axis system for comparison with the above figures. The following equations may be used for this purpose if the sign convention of Figure 2-15 is followed:

a. $n_{z_B} = n_{z_G} \cos\theta + n_{x_G} \sin\theta$

NOTES:

1) LOAD FACTORS ACT THROUGH TARGET CENTER-OF GRAVITY IN BODY AXIS, SEE FIG. 2-15.

2) SEE FIGURE 2-23 FOR LATERAL LOAD FACTOR TO BE COMBINED WITH EACH LETTERED POINT.

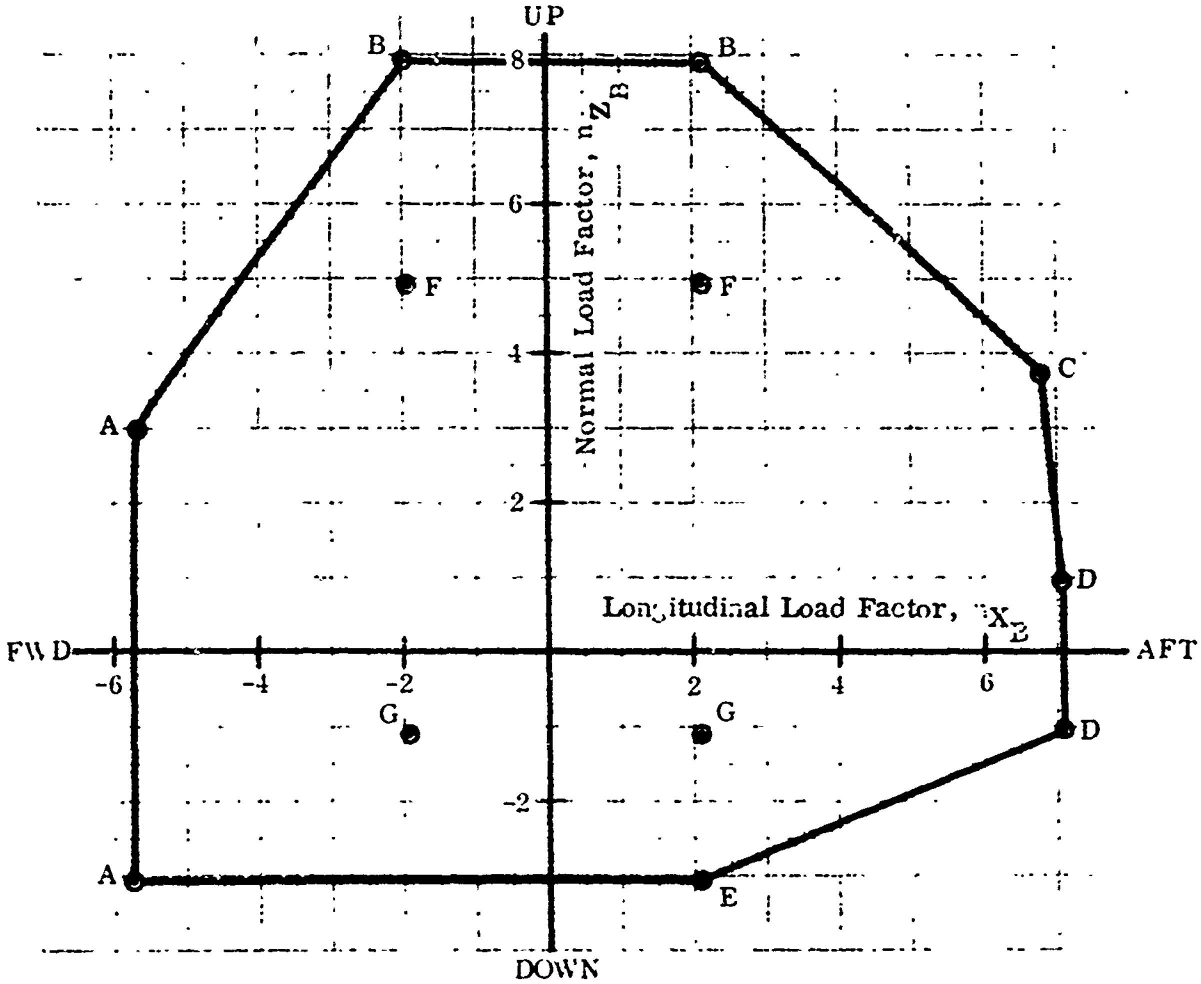


Figure 2-22. BQM-34A (124) Normal/Longitudinal Limit Load Factor Envelope

NOTES:

1) LOAD FACTORS ACT THROUGH TARGET CENTER-OF-GRAVITY IN BODY AXES AND IN DIRECTION OF ACCELERATION

2) SEE FIGURE 2-22 FOR LONGITUDINAL LOAD FACTOR TO BE COMBINED WITH EACH LETTERED POINT CONDITION.

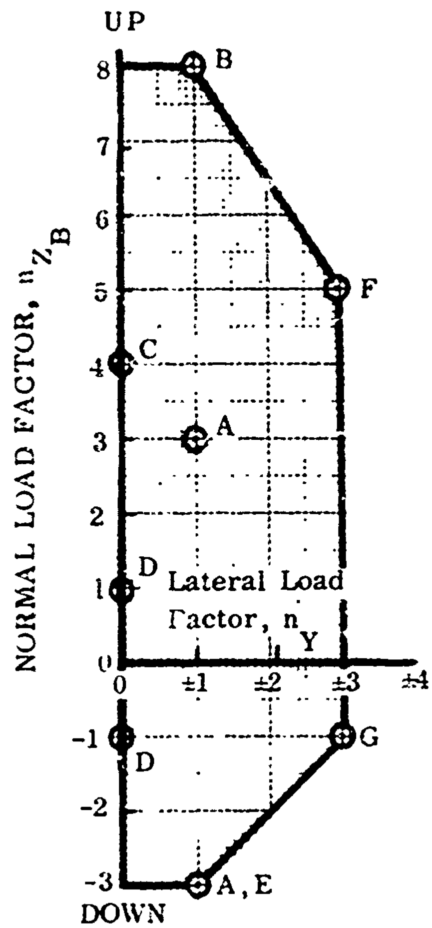


Figure 2-23. BQM-34A (124) Normal/Lateral Limit Load Factor Envelope

NOTES:

1) LOAD FACTORS ACT THRU TARGET CENTER-OF-GRAVITY IN BODY AXES AND IN DIRECTION OF ACCELERATION

2) SEE FIGURE 2-25 FOR LATERAL LOAD FACTOR TO BE COMBINED WITH EACH LETTERED POINT

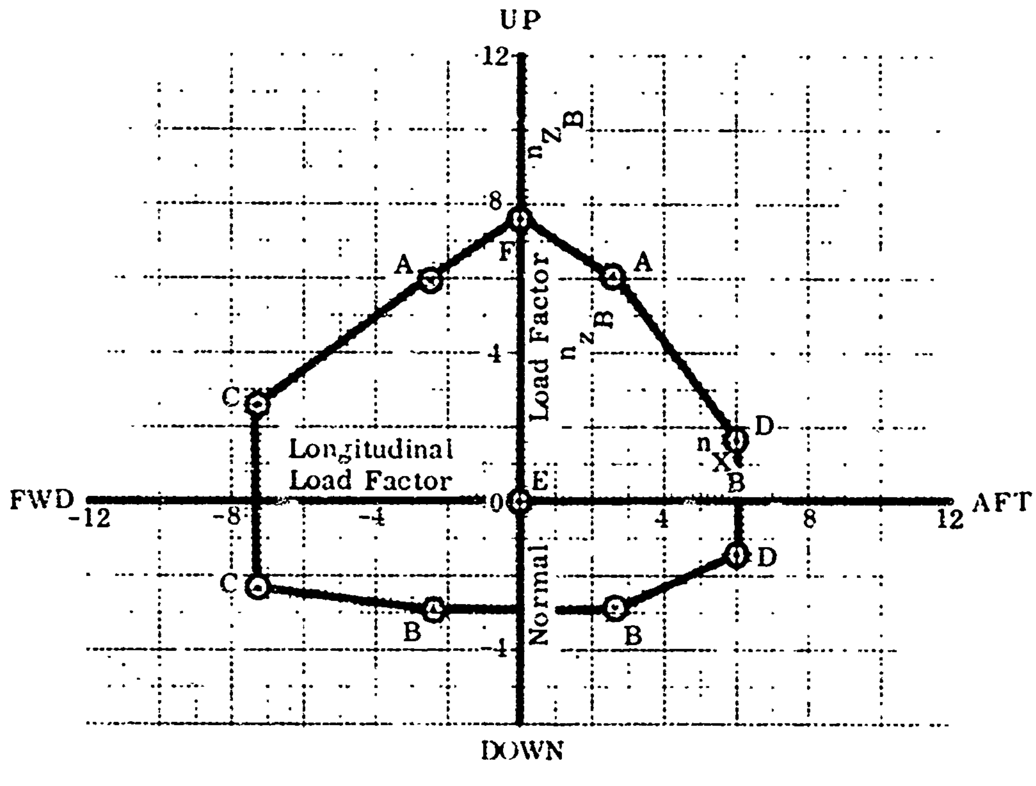


Figure 2-24. BQM-34F (166) Normal/Longitudinal Limit Load Factor Envelope

NOTES: 1) LOAD FACTORS ACT THRU TARGET CENTER-OF-GRAVITY IN BODY AXES AND IN DIRECTION OF ACCELERATION

2) SEE FIGURE 2-24 FOR AXIAL LOAD FACTOR TO BE COMBINED WITH EACH LETTERED POINT.

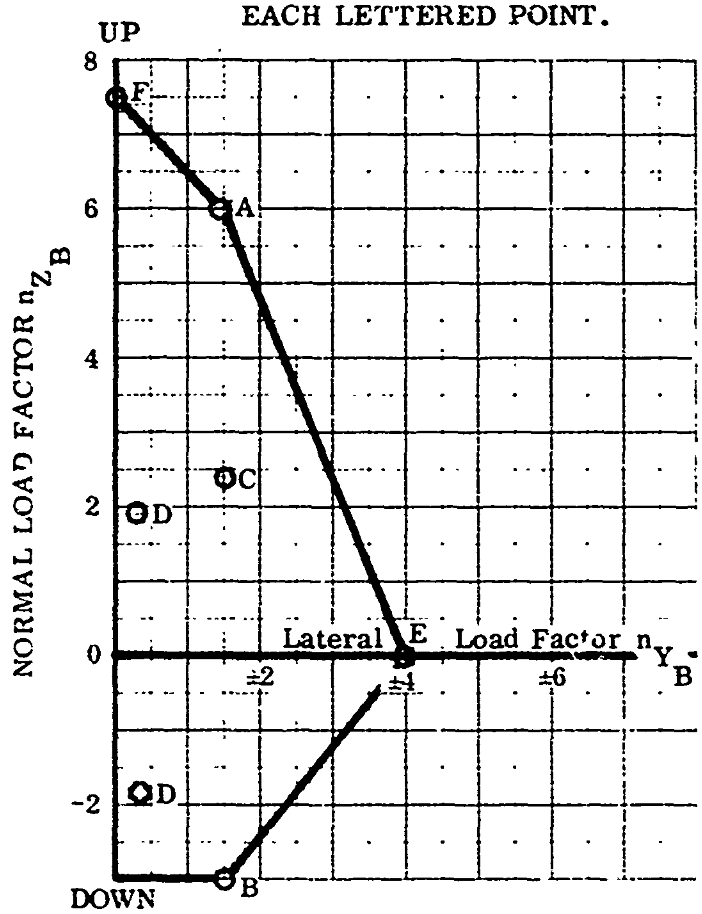


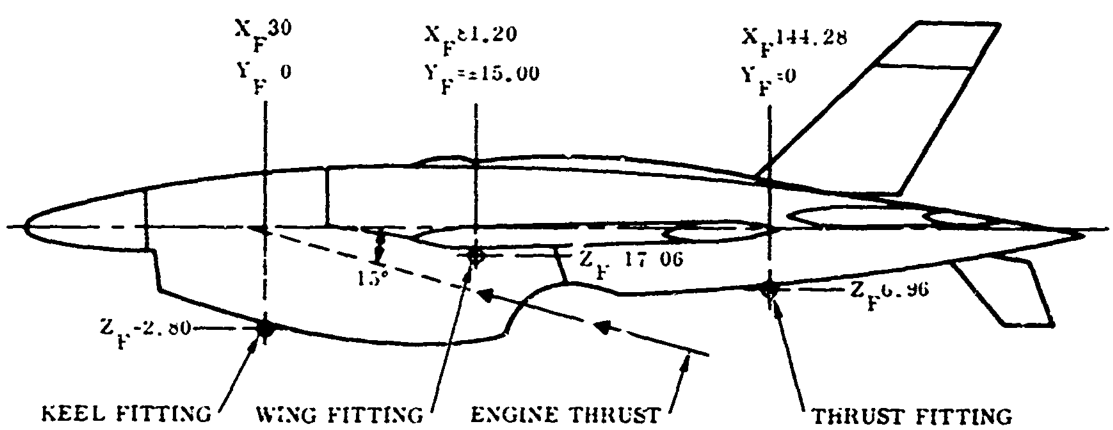
Figure 2-25. BQM-34F (166) Normal/Lateral Limit Load Factor Envelope

b. $n_{x_B} = -n_{z_G} \sin\theta + n_{x_G} \cos\theta$

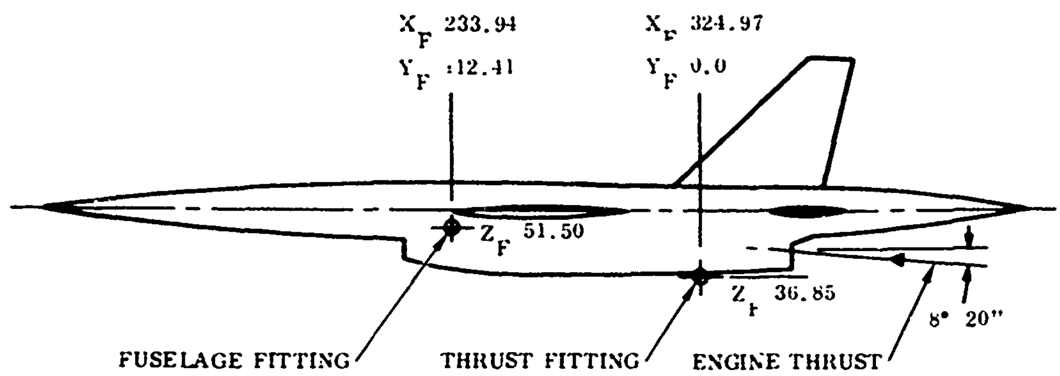
Hold-back requirements for prelaunch engine run-up shall consider, in addition to engine thrust forces, ground winds from any direction. Engine thrust forces are obtained from Figures 2-20 and 2-21. Longitudinal aerodynamic forces for 35-knot ground head or tail winds are obtained from Figures 2-16 or 2-17. For tail winds, multiply the forces shown for 35 KTAS by -1. Forces due to side winds, if applicable, can be obtained from Figures 2-18 and 2-19.

The existing structural hard points on the BQM-34A and BQM-34F targets have been evaluated for their structural load carrying capability. The hard points and their capabilities are discussed below. The total loading applied to all of the hard points should not, for any case, produce load factors in excess of those described above. The hard point loads are presented as limit loads and are the maximum loads that may be applied to the hard points. The limit loads are consistent with an ultimate factor of safety of 1.50 between limit and ultimate.

The existing BQM-34A and BQM-34F hard points are illustrated in the following sketches:



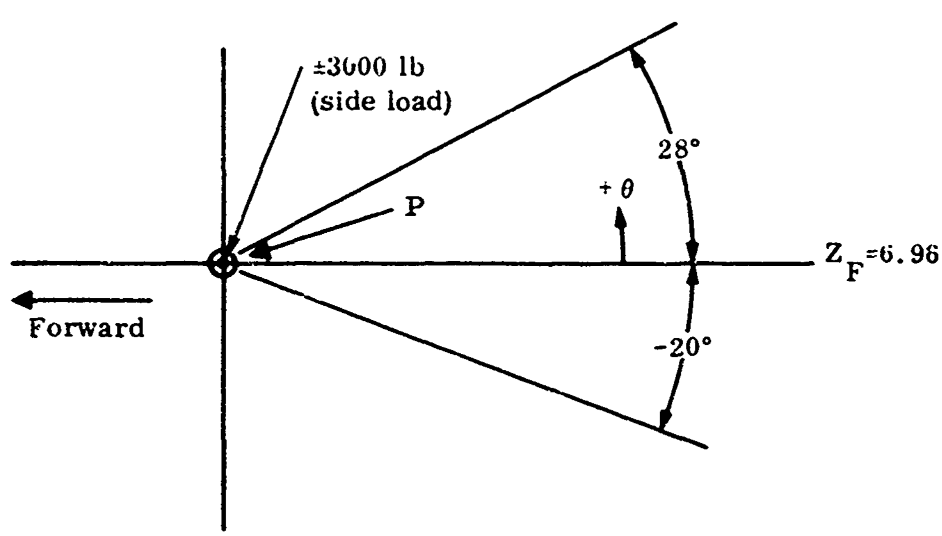
BQM-34A HARD POINT LOCATIONS



BQM-34F HARD POINT LOCATIONS

2.5.3 BQM-34A Hard Points

Thrust fitting at X_F = 144.28, Y_F = 0.0, Z_F = 6.96. This fitting and its attachment were designed for introducing rocket motor thrust loads during ground launch. Stress analysis indicates that the fitting attachment to the fuselage is critical under axial loads with a downward component as shown in the sketch below. The launch fitting installation and fuselage structure is not critical under reasonable side loads and an arbitrary value is used. Limit allowable loads are shown in the following sketch. Loads may act independently or concurrently.



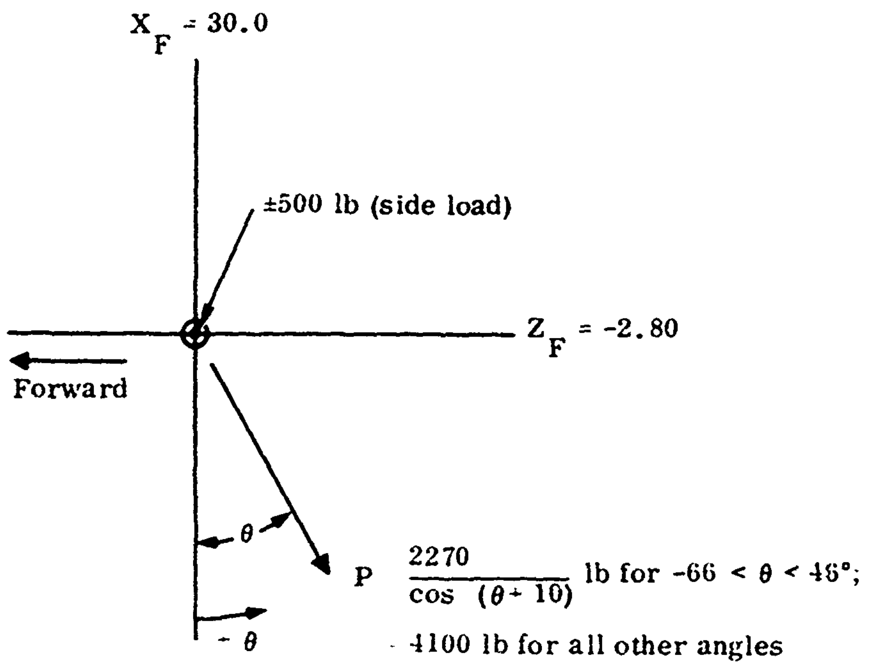
X_F = 144.28

$P = 14000$ lb $(-20° \le \theta \le 28°)$

$$P = \frac{5470}{(\theta - 5°)} \quad (28° < \theta \le 90°)$$

Keel fitting at $X_F = 30.0$, $X_Y = 0.0$, $Z_F = -2.8$. The keel fitting was designed for loads in the vertical plane introduced during ground launch during rocket-motor thrust build-up. Loads are introduced through a steel spool which clamps the channel sides of the keel member. The failure mode under loads in the vertical plane is tension failure at the hole edge. The hole edge is critical in bending under side loads.

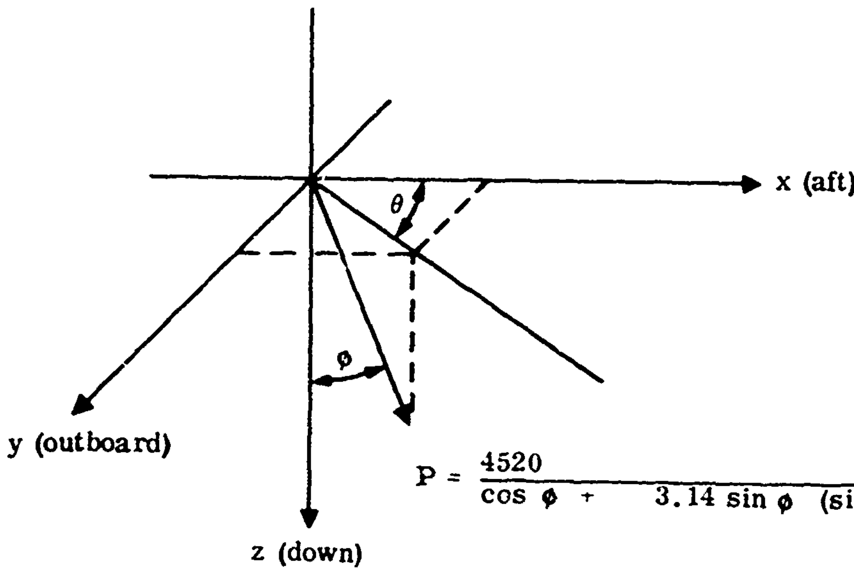
Allowable limit loads are illustrated below. Loads may act independently or concurrently.



Wing fittings at $X_F = 81.2$, $Y_F = \pm15.0$, $Z_F = 17.06$. These fittings are attached to the lower surface of the wing and react longitudinal, lateral and vertical loads. The fitting is capable of 5,000-pound limit upward (i.e., compressive) vector load acting in a 45-degree cone about the vertical axis. The fitting capability for downward load is limited by fastener tension allowables. A design equation based on a load vector and fastener tension capability was derived and is illustrated on the following page. Due to attachment symmetry about the lateral axis, this equation is also valid for forward longitudinal loads.

Allowable limit loads, when acting separately, are:

$$P_z = 4,520 \text{ Pounds}, \; P_x = \pm 4,000 \text{ Pounds}, \; P_y = \pm 1,440 \text{ Pounds}$$



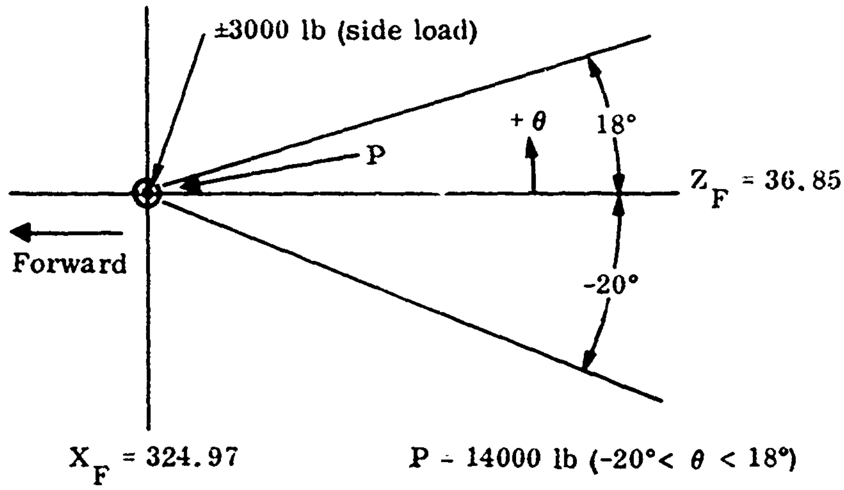
$$P = \frac{4520}{\cos\phi + 3.14 \sin\phi \; (\sin\theta + .36 \cos\theta)} \text{ lb}$$

ϕ = angle between the vertical axis and the load vector ($0 < \phi < 90°$)

θ = angle between the x-axis and the projection of the load vector on the x-y plane ($-90° < \theta < 90°$)

2.5.4 BQM-34F Hard Points

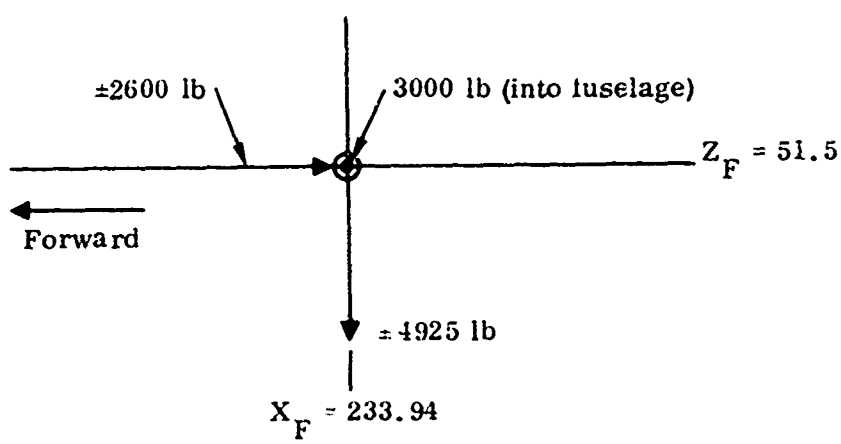
Thrust fitting at $X_F = 324.97$, $Y_F = 0.0$, $Z_F = 36.85$. This fitting and attachment was designed for rocket motor loads during ground launch. Stress analysis indicates that the fitting and attachment is critical under axial loads with a downward component as shown in the sketch on the following page. The fitting installation and fuselage structure are not critical under reasonable side loads and an arbitrary value is established. The following limit loads may act independently or concurrently.



$P = 14000$ lb $(-20° < \theta < 18°)$

$$P = \frac{4326}{\sin \theta} \quad (18° < \theta < 90°)$$

Fuselage support fittings at $X_F = 233.94$, $Y_F = -12.14$, $Z_F = 51.5$. Socket fittings machined in a boss in the frame at X_F 233.5 transmit ground handling and ground launch loads to the frame. The frame is not critical for in-plane (i.e., lateral) loads and arbitrary limit loads are established. Stress analysis for longitudinal loads at the fitting provides an allowable limit load of 2,600 pounds. Allowable limit loads are illustrated below. Loads may act independently or concurrently.



2.6 SIMULATION

2.6.1 BQM-34A Catapult Launch

The significant parameters affecting the catapult launch of a BQM-34A (Teledyne Ryan Model 124) with the LSI A/A37G-8 autopilot have been investigated using an EAI 8400 digital computer and a six-degree-of-freedom simulation representing an assumed worst case configuration. The worst case configuration consists of basic BQM-34A aerodynamic data with a drag increment of $\Delta C_D = 0.0132$ to account for two 11-inch diameter Hayes CIR pods. The weight used was 3,000 pounds (gross) with a center-of-gravity position at X_F 86.3 inches (3% MAC). The launch analysis was conducted at a pressure altitude of 5,000 feet and an ambient temperature of 105°F. Engine rpm was constant at 100 percent.

Aerodynamic derivatives and other characteristics for the simulation were obtained from Reference 4.

The analysis has resulted in establishing a minimum speed of 465 feet per second at which the above configuration can be successfully launched with worst case aerodynamic asymmetries and a 15-knot tail wind (15-knot cross winds were found to be less restrictive). The study has also shown that a pitch attitude command of 20 degrees and an initial pitch attitude of 10 degrees give the most acceptable launch and climbout for the configuration studied.

A brief examination of several other weight and center-of-gravity combinations has indicated a requirement for further study of other configurations. Heavy weight, aft center-of-gravity configurations may require a reduction in the pitch attitude command.

The launch analysis and results are predicted on certain criteria used to define an acceptable launch. These criteria are as follows:

a. Bank angle not to exceed ±40 degrees.

b. Control surface deflections not to be mechanically limited for more than three (3) seconds.

c. Altitude rate always greater than zero.

d. Velocity during launch and climbout sufficient to maintain steady-state angle of attack less than 10 degrees.

All of the criteria must be satisfied to qualify as an acceptable launch.

The vehicle configuration was an assumed worst case; that is, high weight, forward center of gravity, most adverse aerodynamic and thrust asymmetries are as shown below:

a. Gross Weight = 3,000 Pounds

b. Center of Gravity at X_F 86.3

c. Basic Model 124 aerodynamics with $\Delta C_D = 0.0132$ for the two Hayes CIR pods

d. Aerodynamic Asymmetries:

(1) $\Delta C_n = 0.006$

(2) $\Delta C_\ell = 0.005$

(3) $\Delta C_Y = 0.011$

e. Engine at 100 percent rpm

f. Engine sideforce and yawing moment from 1 percent gross thrust applied at the tail pipe exit

g. The BQM-34A FCS could not be significantly modified

The launch analysis was conducted at a pressure altitude of 5,000 feet and a temperature of 105°F. The effect of surface winds was also evaluated using 15 knots for cross and tail winds and 35 knots for head wind.

Since the catapult design is not known, ground effects and any initial interference effects with the catapult hardware could not be considered.

The information contained above was incorporated in a six-degree-of-freedom program utilizing an EAI 8400 digital computer. This simulation was then used to determine the minimum speed for an acceptable launch for any given pitch attitude and pitch attitude command.

Results

The results of the simulation effort to evaluate the catapult launch characteristics of an assumed worst case BQM-34A are contained in Figures 2-26 through 2-31. Figure 2-26 presents the minimum launch speed requirements for the vehicle. Included in this figure are the effects of

5000 FEET @ 105 DEGREE F

GROSS WEIGHT = 3000 POUNDS, 100% RPM

ASYMMETRIES:

1) 1% GROSS THRUST SIDEFORCE & YAWING MOMENT (NEG. ΔCn)
2) $\Delta C_n = -.006$
3) $\Delta C_y = +.011$
4) $\Delta C_l = -.006$

APPROXIMATE HORIZONTAL DISTANCE TO ΔH = 200 FT.

θ_{CMD}	HOR. DIST.
10°	14,000 FT
15°	9,000 FT
20°	7,000 FT
25°	4,000 FT

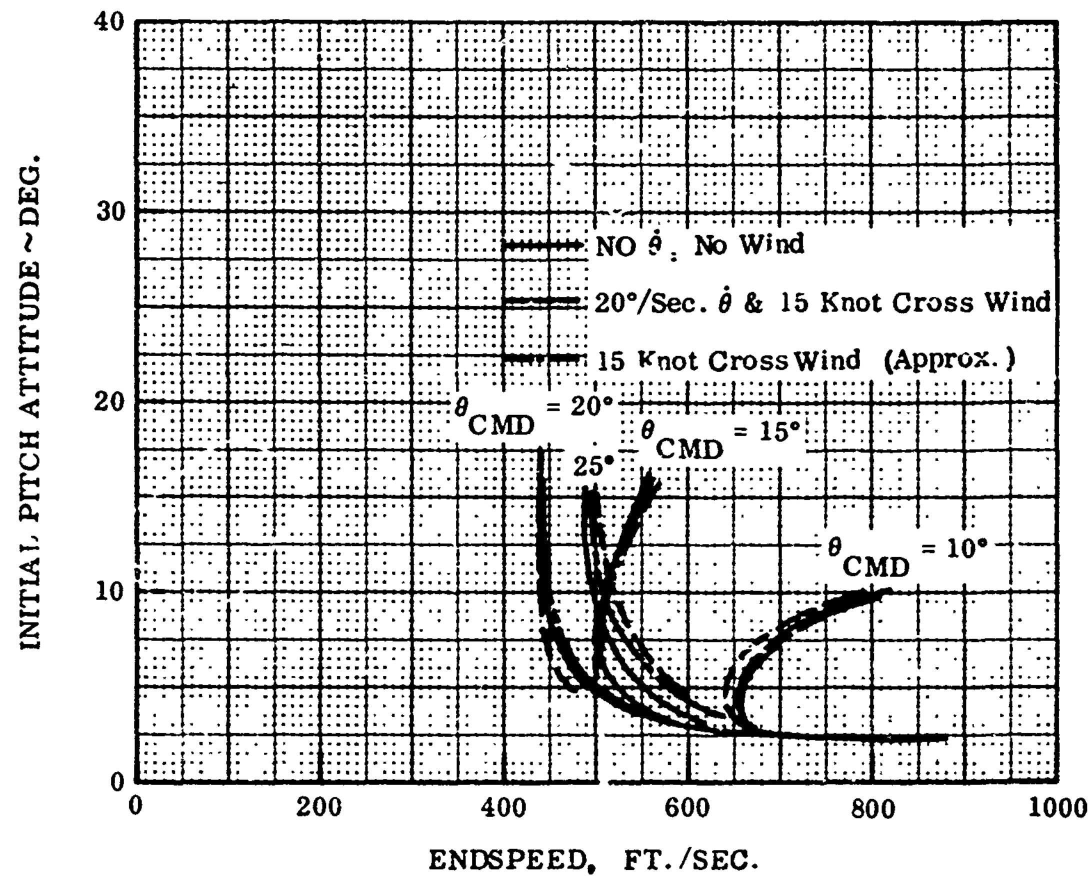


Figure 2-26. BQM-34A (124) Catapult Launch With Airframe and Thrust Asymmetries and 15-Knot Crosswind

crosswinds and initial pitch rate. Note that the airframe and thrust asymmetries are worst case values and have been added to produce the most adverse effect. In addition, the effect of 15-knot crosswinds was evaluated with its influence added to the asymmetries.

In Figure 2-26, it can be seen that in general as pitch attitude and pitch attitude command are increased, the allowable launch speed is reduced. A reversal of this trend is most apparent for θ_{CMD} = 10 degrees, $\theta >$ 5 degrees. This is due to a mismatch between the attitude and command resulting in a detrimental launch transient. This transient must be overcome with a higher launch velocity. A pitch attitude command of 20 degrees permits the minimum launch velocity to be obtained. At a pitch command of 25 degrees, the vehicle asymmetries begin to dominate causing $\phi >$ 40 degrees and requiring a higher speed for an acceptable launch. Note that no data with 15-knot tail winds are shown but that this may be simply obtained by adding 15 knots (25 fps) to the no-wind data.

Figure 2-27 shows the required launch speeds for the 3,000-pound vehicle without any asymmetries or winds. It is obvious from examining these first two figures that the vehicle asymmetries play a significant part in the launch dynamics as reflected by the increase in launch speed due to asymmetries. A cursory investigation into the vehicle launch characteristics at various centers of gravity and weights other than the assumed worst case has pointed up a need to carefully examine a range of vehicle configurations to find the best pitch attitude command for each. For example, configurations with an aft center of gravity may be more effectively launched with a pitch command lower than 20 degrees or perhaps even at a lower velocity. A lower pitch command for the worst case configuration would, however, require higher speeds and result in a slower climb rate. The effect of pitch attitude command on the distance required to climb 200 feet is shown in the upper right hand portion of Figures 2-26 and 2-27.

Figure 2-28 presents data extracted from Figure 2-26 with the addition of a 15-knot tail wind and the added variable of gross weight. Data are only presented for a pitch attitude command of 20 degrees since this was deemed the best for the assumed worst case configuration. The curve in Figure 2-28 for 3,000 pounds, which as stated includes the effect of a 15-knot tail wind, was used to establish the minimum acceptable launch speed of 465 feet per second. Shown on the figure is the region considered to produce a satisfactory launch of the assumed worst case vehicle.

Figures 2-29, 2-30, and 2-31 present representative launches of the worst case vehicle at various pitch attitudes around the chosen value of 10 degrees

5000 FEET @ 105 DEGREE F

GROSS WEIGHT = 3000 POUNDS, 100% RPM

NOTE:

1) NO AIRFRAME OR THRUST ASYMMETRIES
2) NO WINDS

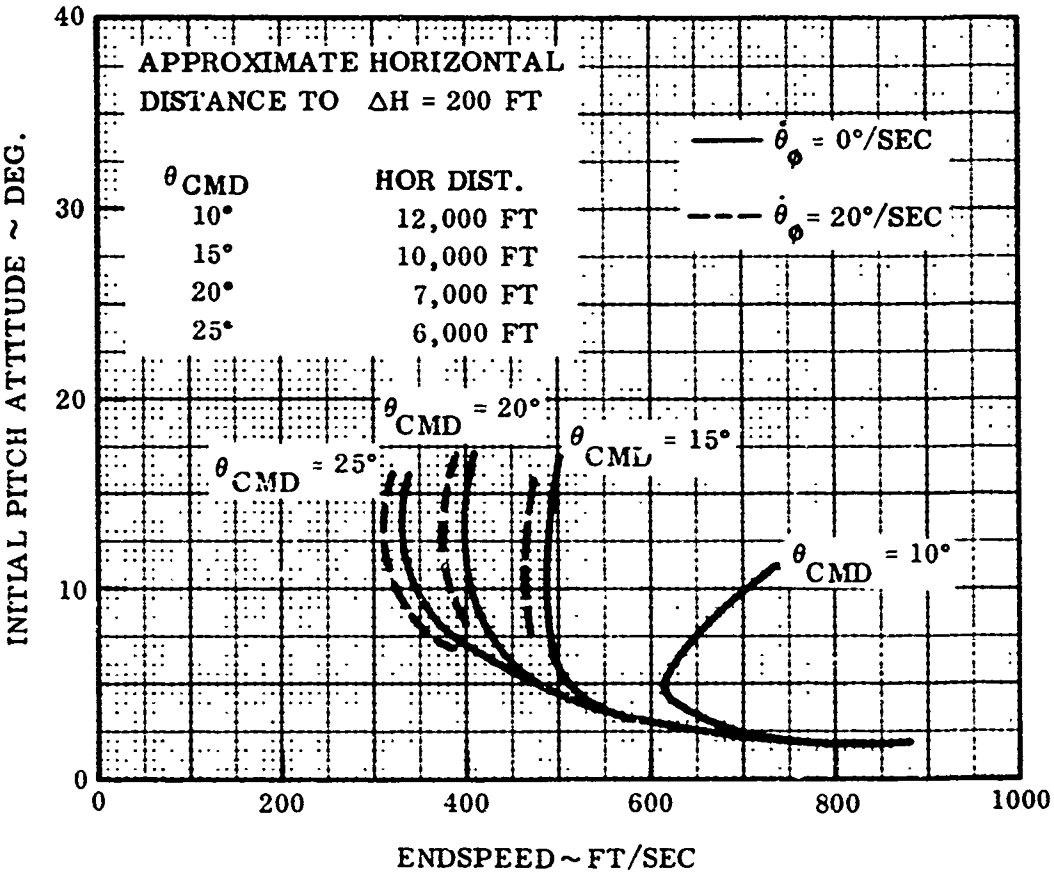


Figure 2-27. BQM-34A (124) Catapult Launch Without Airframe and Thrust Asymmetries and No Wind

θ_{CMD} = 20 DEGREES, 15-KNOT TAILWIND
GROSS WEIGHT = 3,000 POUNDS (2,500, 2,000 POUNDS ALSO SHOWN)

C.G. @ F.S. 86.3 INCHES
ALT = 5,000 FEET
TEMP = 105°F
RPM = 100%

ASYMMETRIES

1) 1 PERCENT GROSS THRUST SIDEFORCE AND YAWING MOMENT (NEG. ΔC_n)
2) AERO: $\Delta C_n = -0.006$
   $\Delta C_\ell = -0.006$
   $\Delta C_y = 0.011$

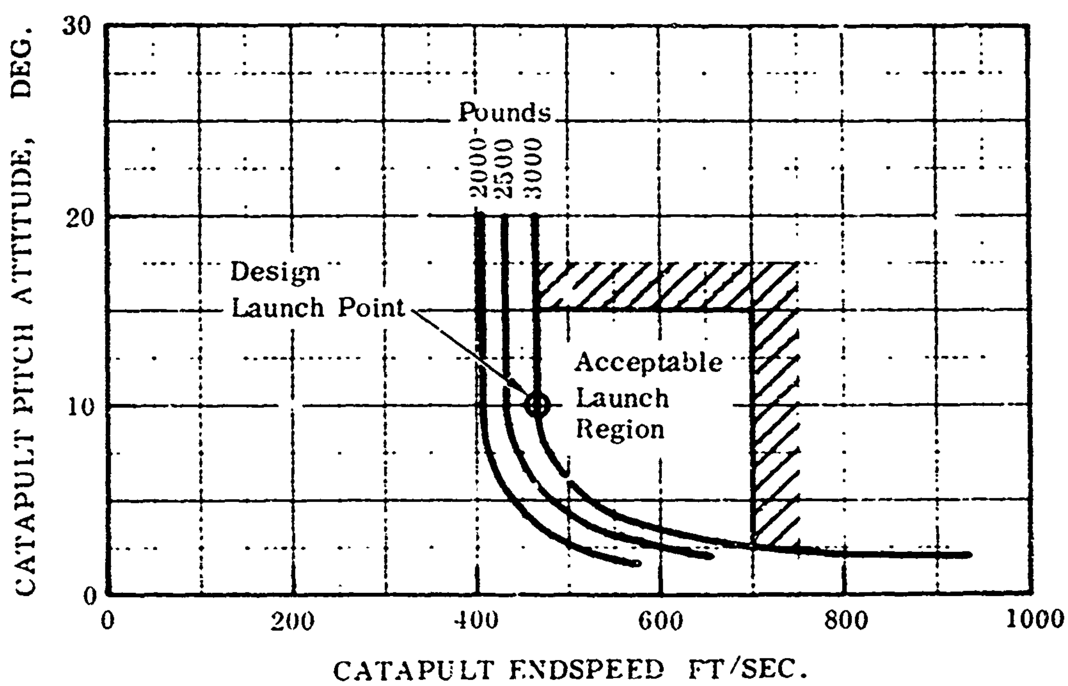


Figure 2-28. BQM-34A (124) Catapult Launch With Airframe and Thrust Asymmetries and 15-Knot Tailwind

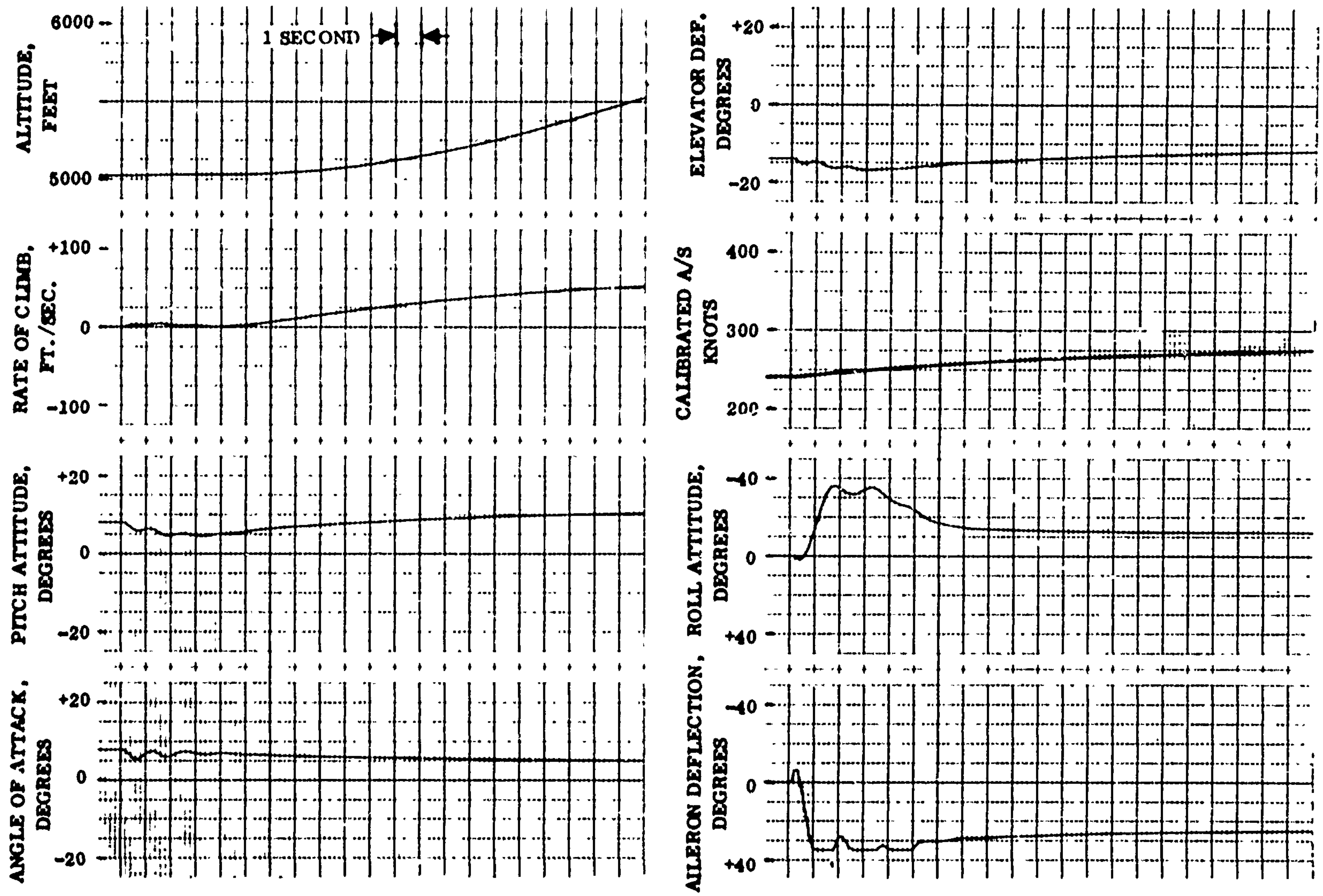


Figure 2-29. Vehicle Launch, BQM-34A, θ_{cmd} = 20 Degrees, θ_o = 8 Degrees, V_o = 465 Ft./Sec., 15-Knot Crosswind, Gross Weight = 3,000 Pounds

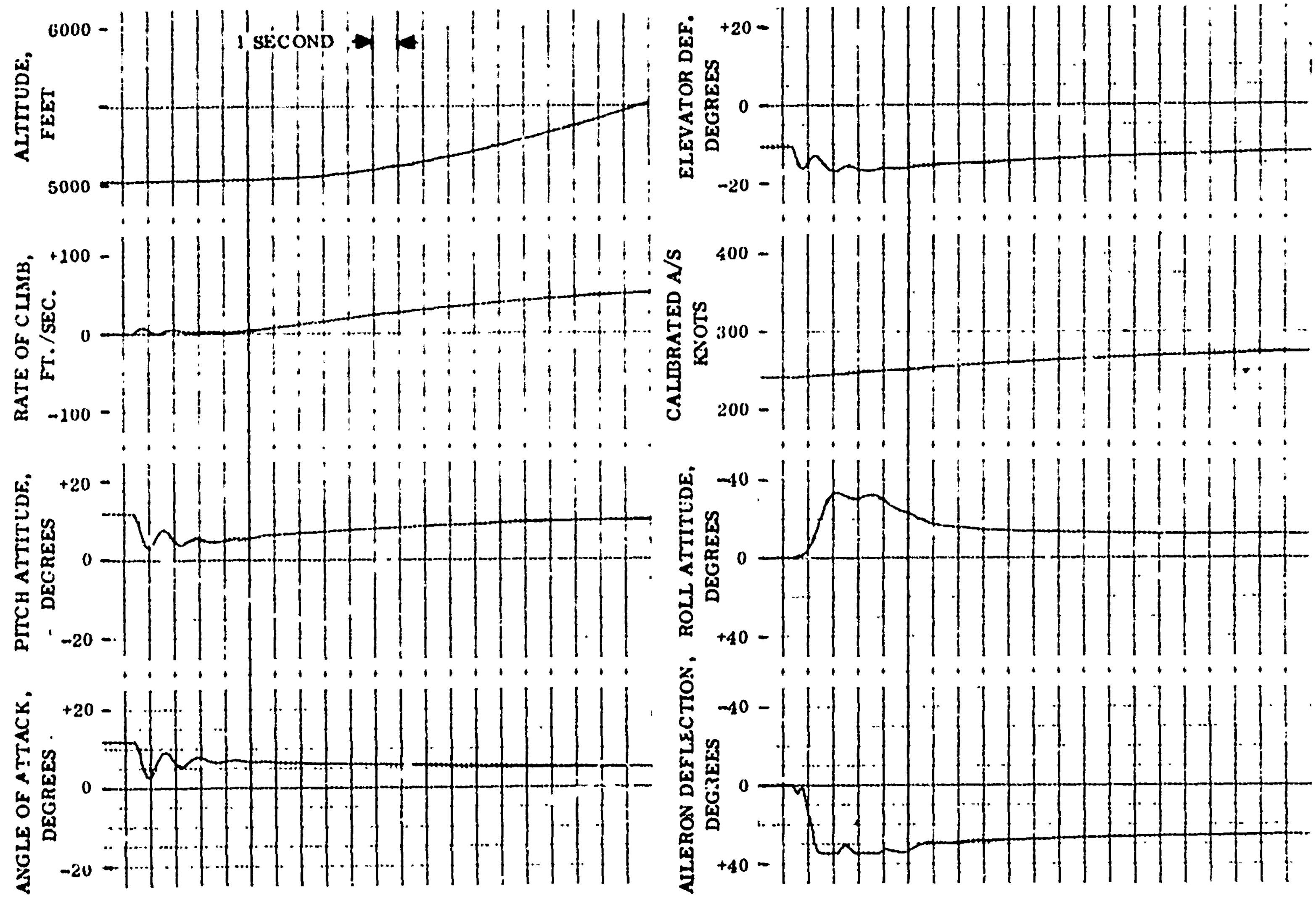


Figure 2-30. Vehicle Launch, BQM-34A, θ_{cmd} = 20 Degrees, θ_o = 10 Degrees, V_o = 465 Ft./Sec., 15-Knot Crosswind. Gross Weight = 3,000 Pounds

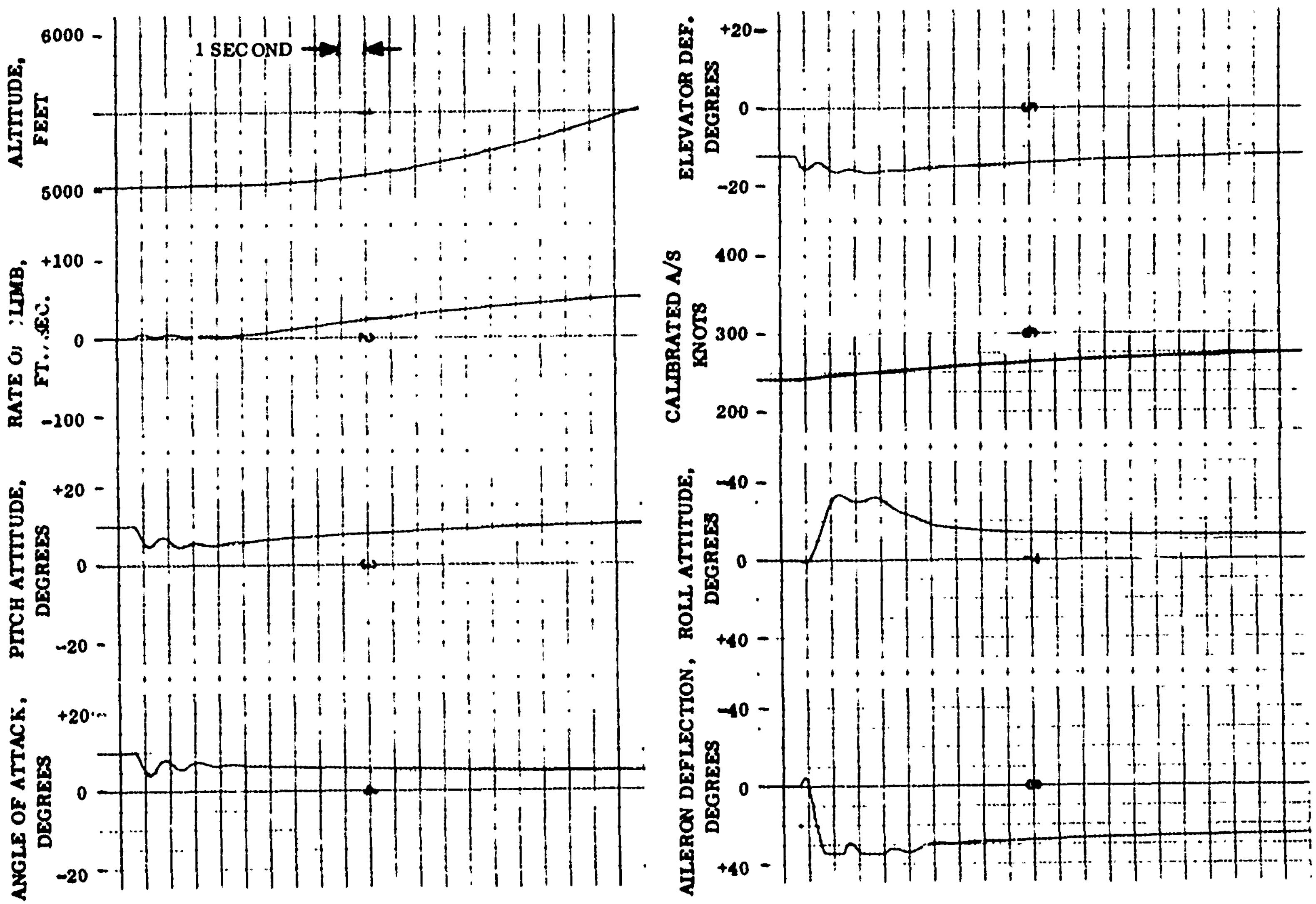


Figure 2-31. Vehicle Launch, BQM-34A, θ_{cmd} = 20 Degrees, θ_o = 12 Degrees, V_o = 465 Ft./Sec., 15-Knot Crosswind, Gross Weight = 3,000 Pounds

with the pitch command at 20 degrees. A pitch attitude of 10 degrees ± 1 is considered to produce the best compromise between roll, initial rate of climb, longitudinal transient and control surface positions.

Figure 2-32 presents the launch climbout trajectory of the vehicle with a 15-knot tail wind. This represents the climbout requiring the most horizontal distance to gain an altitude of 200 feet. As noted previously, lower pitch commands will require more distance for the same altitude gain.

Conclusions

The conclusions of the assumed worst case configuration are as follows:

a. Catapult launch of the assumed worst case configuration can be best achieved with rpm = 100 percent, θ = 10 degrees, θ_{CMD} = 20 degrees and V_o = 465 feet per second.

b. Lightweight vehicles (2,000 pounds) can be launched at speeds approaching 400 feet per second.

c. In general. pitch attitude commands greater or less than 20 degrees require higher catapult velocities to launch the vehicle considered in the study.

d. Horizontal distance required to achieve an altitude gain of 200 feet is inversely related to θ_{CMD}. The lower (smaller) the command, the longer the distance.

e. Other vehicle configurations must be adequately analyzed to assure successful launch and to establish the most adequate pitch command for each case.

2.6.2 BQM-34F Catapult Launch

The purpose of the catapult launch analysis was to determine technical parameters for a preliminary target vehicle/catapult interface specification. The basic flight dynamics objective was to investigate and determine the initial pitch attitude and minimum launch velocity to satisfy an assumed worst case configuration and condition. To accomplish this objective, a six-degree-of-freedom digital flight simulation computer program was developed to represent the vehicle airframe dynamics, gyro dynamics, autopilot logic and circuitry including the transfer functions of the components, and the engine performance characteristics as the vehicle leaves the catapult. The basic simulation program is described in Reference 5

$\theta_o = 10°$, $\theta_{CMD} = 20°$, 15 KT TAILWIND

GROSS WEIGHT = 3000 POUNDS

C.G. @ F.S. 86.3 IN.

ALT = 5000 FEET

TEMP = 105°F

RPM = 100%

V_o = 465 FT./SEC.

ASYMMETRIES

1) % GROSS THRUST SIDEFORCE & YAWING MOMENT (NEG. ΔC_n)

2) AERO: $\Delta C_n = -0.006$

$\Delta C_\ell = -0.006$

$\Delta C_y = 0.011$

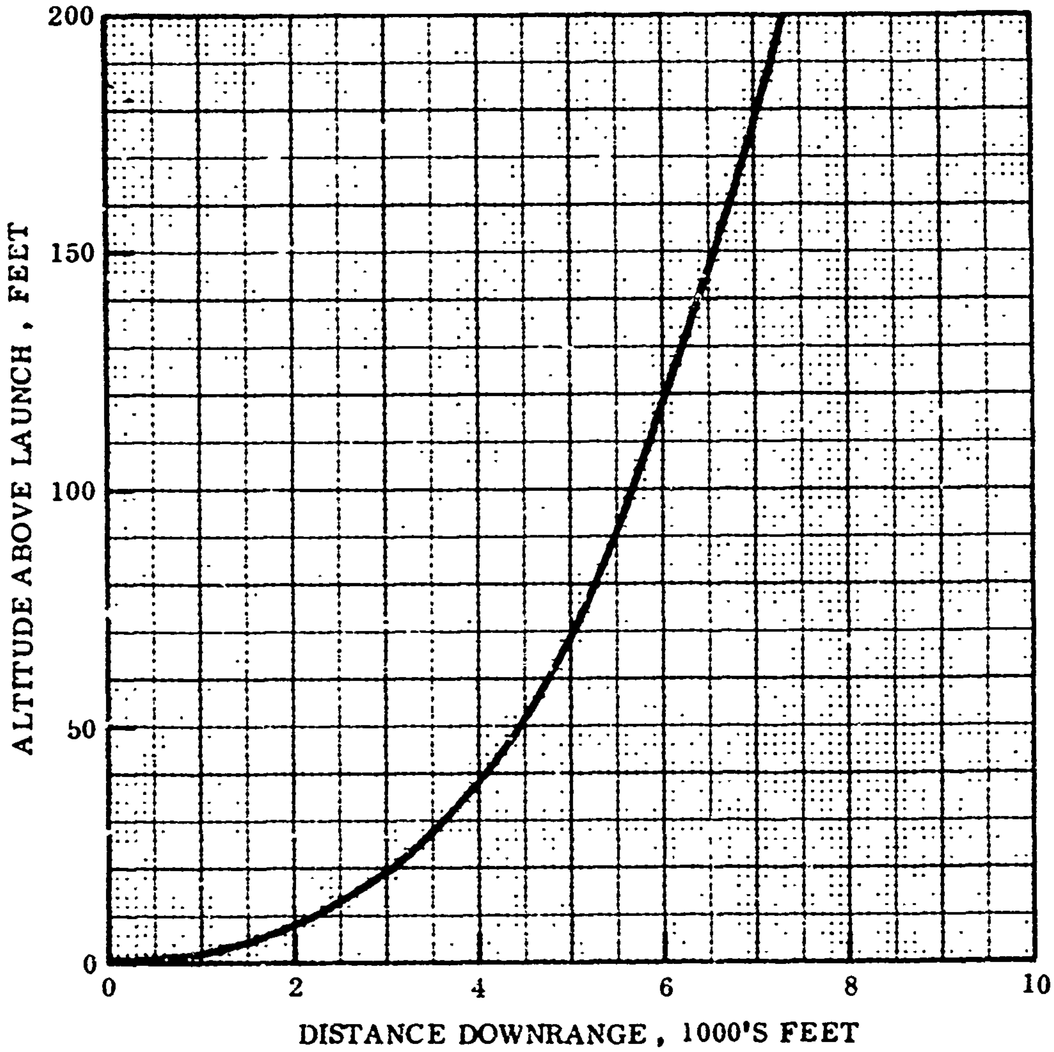


Figure 2-32. BQM-34A (124) Catapult Launch Trajectory

and the general arrangement of the vehicle is illustrated in Figure 2-2. The LSI A/A37G-9 autopilot and control mode logic are based on Reference 6, the basic aerodynamics on Reference 7, and the hot day engine (105°F) at 5,000 feet on Reference 8. The initial launch velocity, pitch attitude, and pitch attitude command were varied while altitude rate, elevon position, angle of attack, separation distances, and other performance and dynamic parameters were monitored. The simulated vehicle was flown in real-time and slower than real-time to properly look at the initial launch in detail. Reference 9 documents the atmospheric model used in the analysis. Equations were derived for the 1962 Standard Atmosphere and modified for the hot day analysis.

A commonly used procedure for off-standard days is to keep the static pressure constant at a specific altitude and vary the temperature which affects the speed of sound, Mach number, and dynamic pressure. Thus, the pressure altitude of 5,000 feet was used with a temperature of 105°F. As altitude was increased above the launch point, the temperature decreased at its standard atmosphere temperature gradient.

Assumptions

The following assumptions were made in the analysis:

a. BQM-34F with IR pods and external fuel tank and full fuel with LSI A/A37G-9 autopilot was the configuration considered.

b. Since the catapult design is not known, ground effects and any initial interference effects with the catapult hardware could not be considered.

c. The worst case configuration and conditions analyzed were as follows:

(1) Heavy weight, 3,000-pound aircraft

(2) Forward center-of-gravity limit, X_F 259.04 inches (15% $\bar{c}$)

(3) Launch altitude of 5,000 feet (pressure altitude)

(4) Atmospheric temperature of 105°F

(5) Moments of inertia increased by mass ratio from nominal to heavy weight

(6) Total wind vector: 35 knots head or 15 knots side or tail wind

(7) Lateral engine asymmetry of 1 percent gross thrust applied at tailpipe

(8) Aerodynamic asymmetries as follows:

ΔC_y = 0.0017 (side force coefficient)

ΔC_ℓ = -0.000679 (rolling moment coefficient)

ΔC_n = -0.001032 (yawing moment coefficient)

d. A good launch was assumed using the following criteria:

(1) Positive altitude rate after launch

(2) Increasing velocity during climbout

(3) An elevon control surface should not be on the stops for more than 3 seconds during a transient

(4) Bank angle less than 40 degrees

(5) Angle of attack less than 20 degrees

(6) Launch Mach number less than 0.9

Results

The following results were determined:

a. After analyzing the worst case condition without asymmetries, a RELEASE mode total pitch command of 25 degrees requires the lowest launch velocity as shown in Figure 2-33. This is the same value used for ground launch; so no autopilot hardware changes are required using this value.

b. The good launch boundary considering asymmetries and 25 degrees pitch command is shown in Figure 2-34. Angle of attack and Mach number limitations are evident. The other boundary represents control surface and altitude rate limitations. The control limit boundary is somewhat odd

NO ASYMMETRIES
ALTITUDE; 5000 FEET
TEMPERATURE; 105 DEG. F
WEIGHT; 3000 POUNDS
ENGINE R.P.M. ; 100%
TAIL WIND; 15 KNOTS
FORWARD C.G. LIMIT; 259.04 INCHES
NO INITIAL PITCH RATE

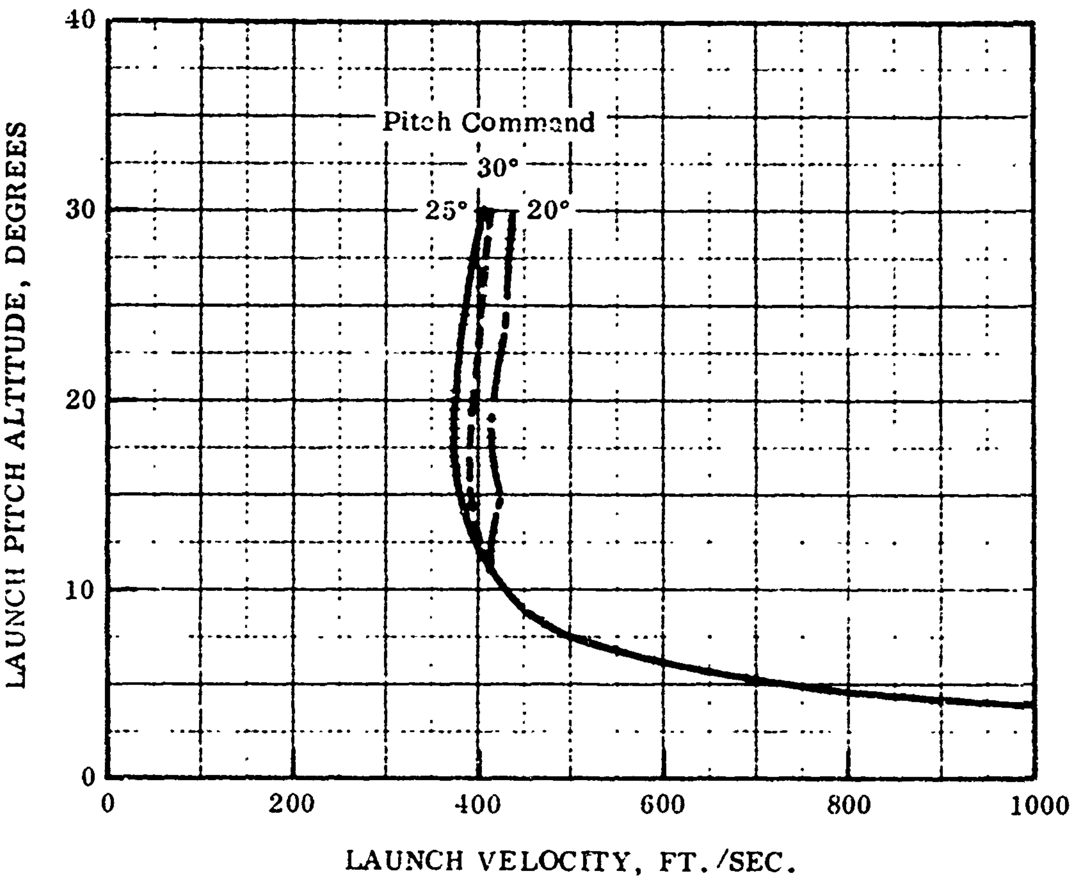


Figure 2-33. Effect of Pitch Command on Minimum Launch Velocity
(BQM-34F Catapult Launch)

ASSUMED WORSE CASE CONDITION

ALTI' DE: 5000 FEET
TEMPERATURE: 105 DEGREE F
WEIGHT: 3000 POUNDS
C.G. STATION: 259.04 INCHES (15% $\bar{c}$)
WIND: 0 TO 35 KNOTS HEAD OR 15 KNOTS SIDE OR TAIL
PITCH COMMAND: 25 DEGREES
INITIAL PITCH RATE: 0 DEG/ SEC.
ENGINE R.P.M. : 100%
ENGINE ASYMMETRIES: 1% LATERAL
AERODYNAMIC ASYMMETRIES

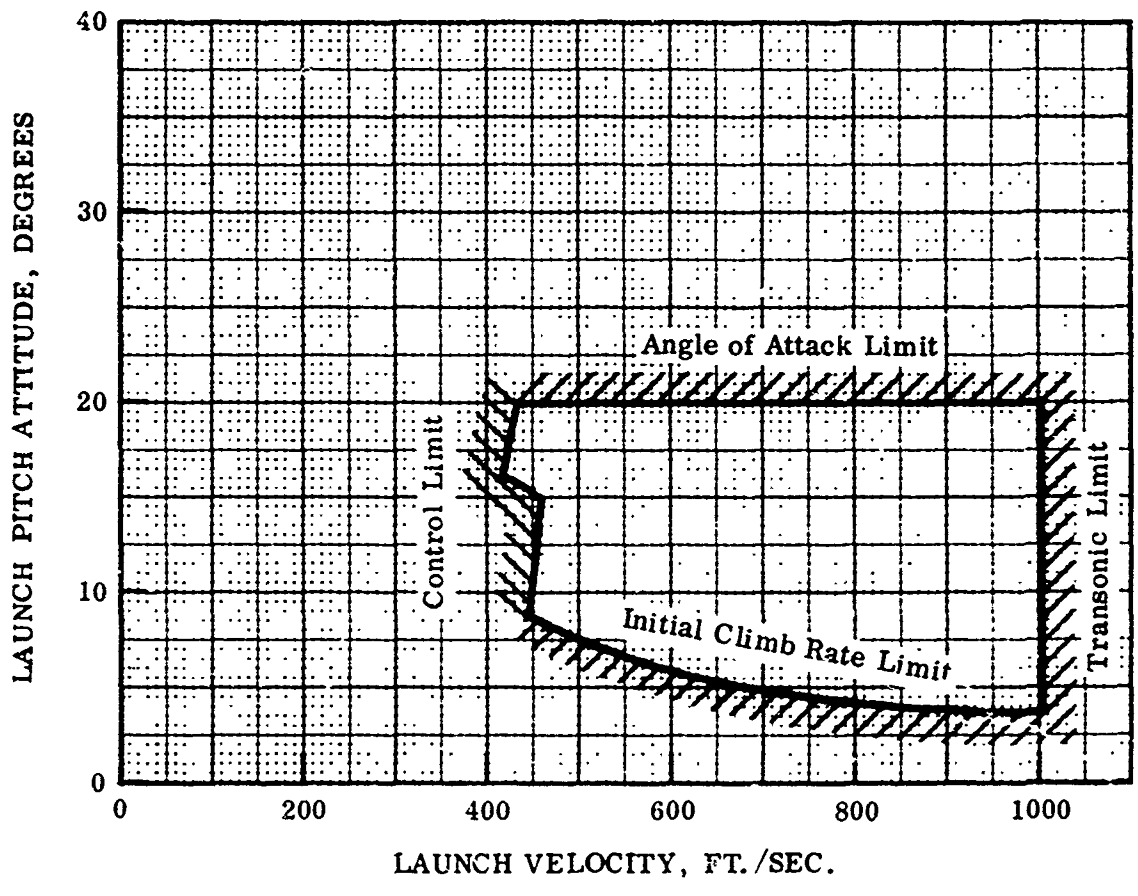


Figure 2-34. Good Launch Boundary (BQM-34F Catapult Launch)

because it is a dynamic limit. Further, the fuel tanks are not completely full, and center-of-gravity variations with fuel angle (considering fuel loading) were used in the analysis.

c. An initial pitch attitude of 10 degrees plus or minus 1 degree is recommended after analyzing the climb-out from catapult separation for the boundary conditions.

d. A minimum end velocity of 450 feet per second is required to satisfy the envelope of possible launch conditions (Figure 2-34, attitude of 10 degrees).

e. The lowest launch velocity can be attained with an engine setting of 100 percent rpm. Thus, it is a requirement.

f. After investigating the range of winds, the tail wind of 15 knots combined with the aerodynamic and engine asymmetries gives the worst case.

g. Some of the dynamic parameters are presented in Figures 2-35, 2-36, and 2-37. The results using the selected pitch attitude (10 degrees) and velocity (450 feet per second) to satisfy the worst case launch condition are shown in Figure 2-35. Decreasing the launch attitude to 8 degrees for the same velocity will result in an initial loss of altitude as illustrated in Figure 2-36 on the fine climb rate scale. Below 10 degrees, the required launch velocity becomes very large to prevent the vehicle from initially dropping. For pitch attitudes above 10 degrees, the control surface tends to go to the up stop of 12 degrees for an extended period of time. Figure 2-37 presents the results for 12 degrees. With the controls on the limit, additional asymmetries could cause the vehicle to roll uncontrolled. The good launch boundary showed the lowest velocity required to be at 16 degrees. However, due to the uncertainties in the aerodynamics at high angles of attack and the above reasons, going above 10 degrees would be questionable at best. Figure 2-38 shows the trajectory for the selected worst case condition.

h. The results showed the vehicle will lose altitude first before it rolls 40 degrees.

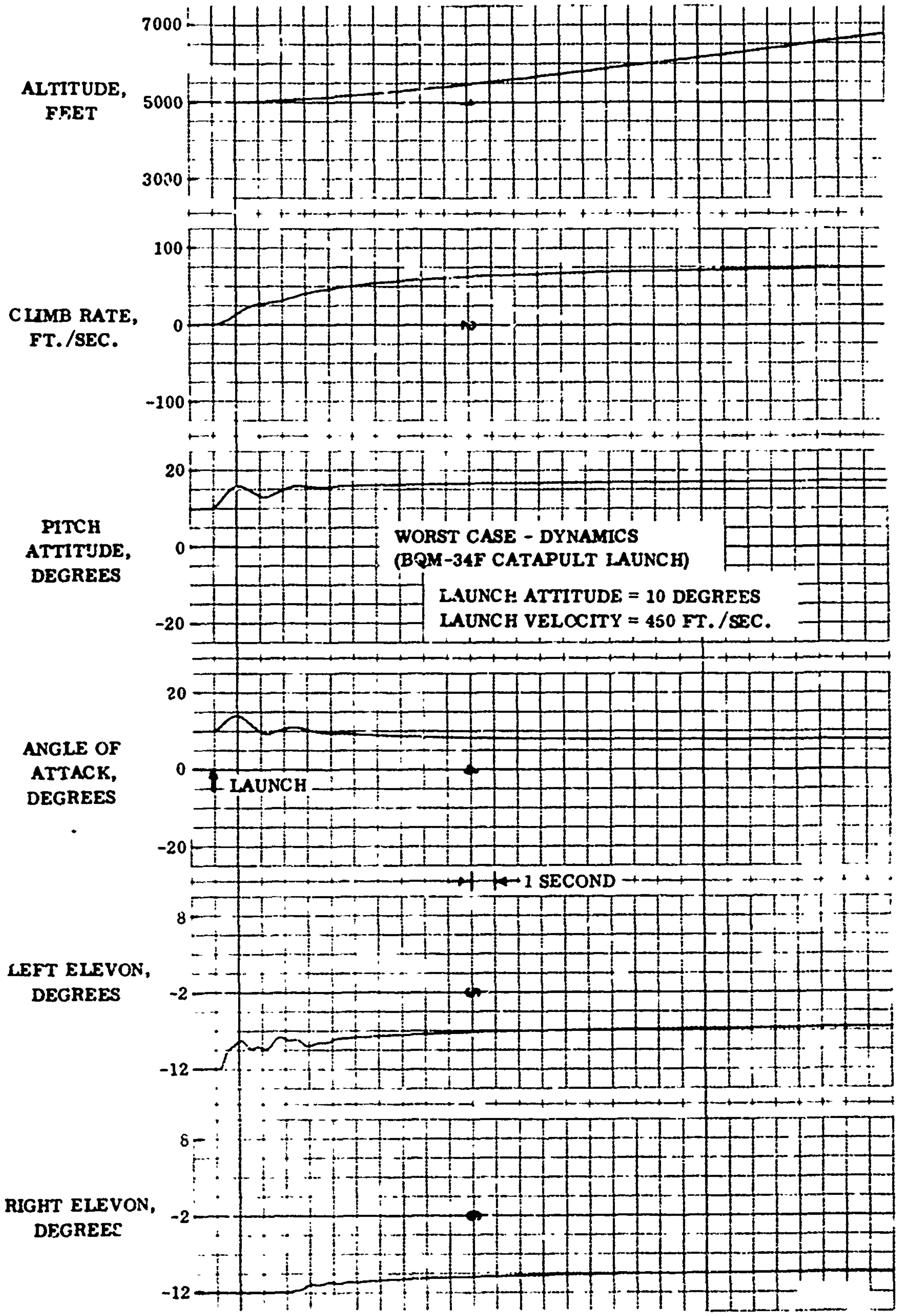


Figure 2-35. BQM-34F Worst Case Dynamics, Launch Attitude = 10 Degrees, Launch Velocity = 450 Ft./Sec.

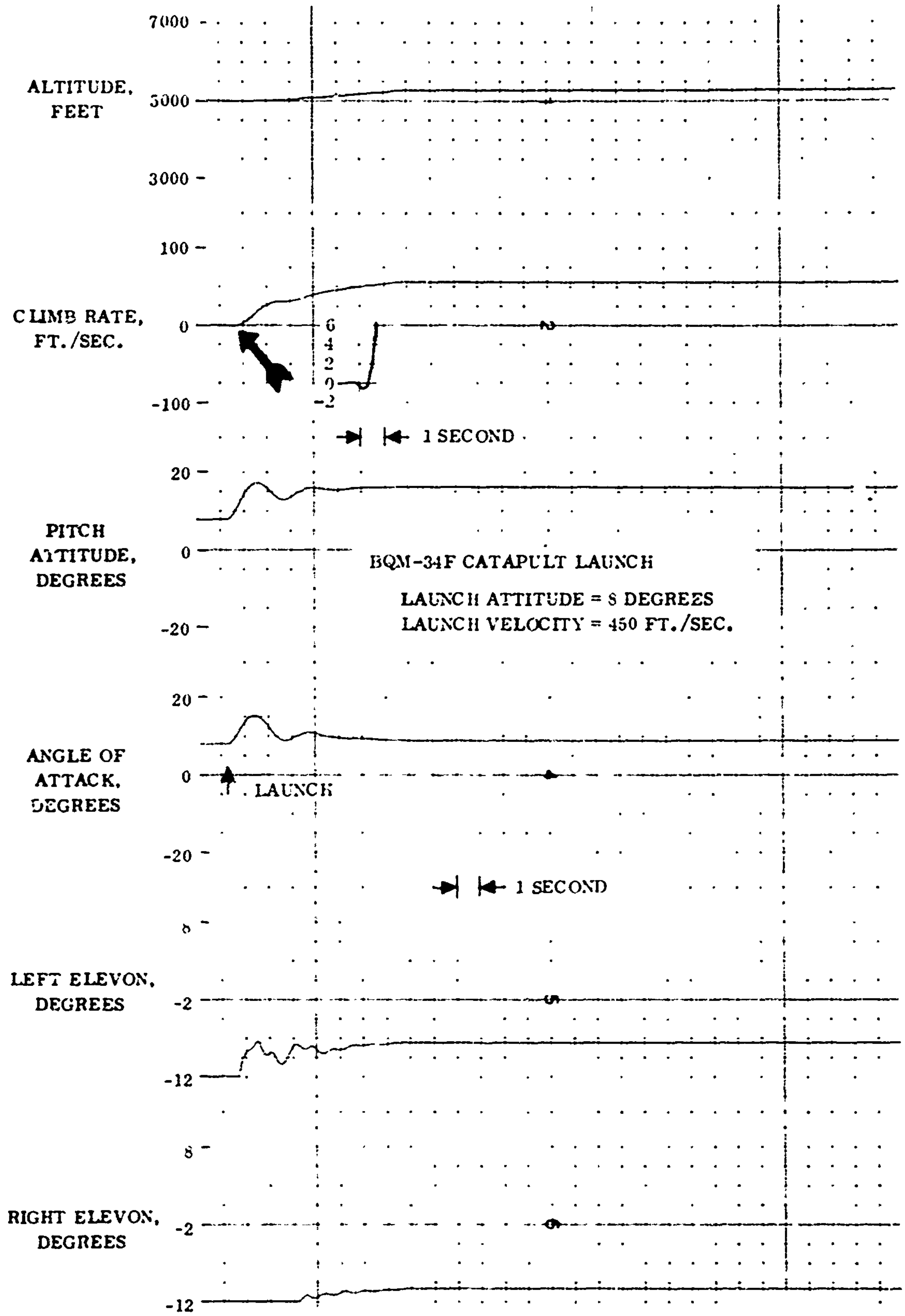


Figure 2-36. BQM-34F Catapult Launch, Launch Attitude = 8 Degrees, Launch Velocity = 450 Ft./Sec.

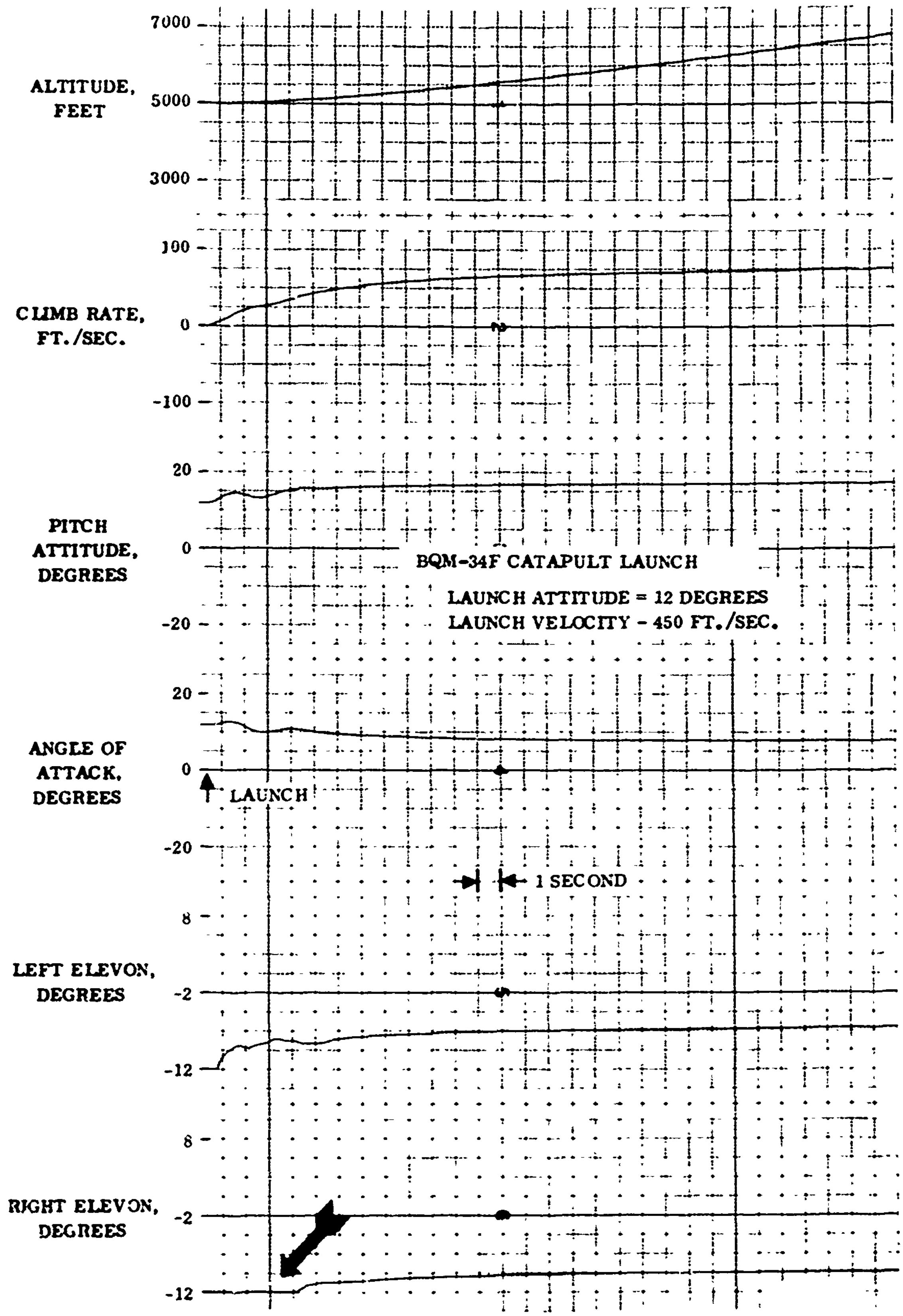


Figure 2-37. BQM-34F Catapult Launch, Launch Attitude = 12 Degrees, Launch Velocity = 450 Ft./Sec.

LAUNCH VELOCITY; 450 FT./SEC. (100% RPM)
LAUNCH ATTITUDE; 10 DEG.
ALTITUDE; 5000 FEET
TEMPERATURE; 105 DEG. F
WEIGHT; 3000 LBS.

PITCH COMMAND; 25 DEG
TAIL WIND; 15 KNOTS
ENGINE ASYMMETRIES; 1 % LATERAL
AERODYNAMIC ASYMMETRIES
FORWARD C.G. LIMIT; 259.04 INCHES

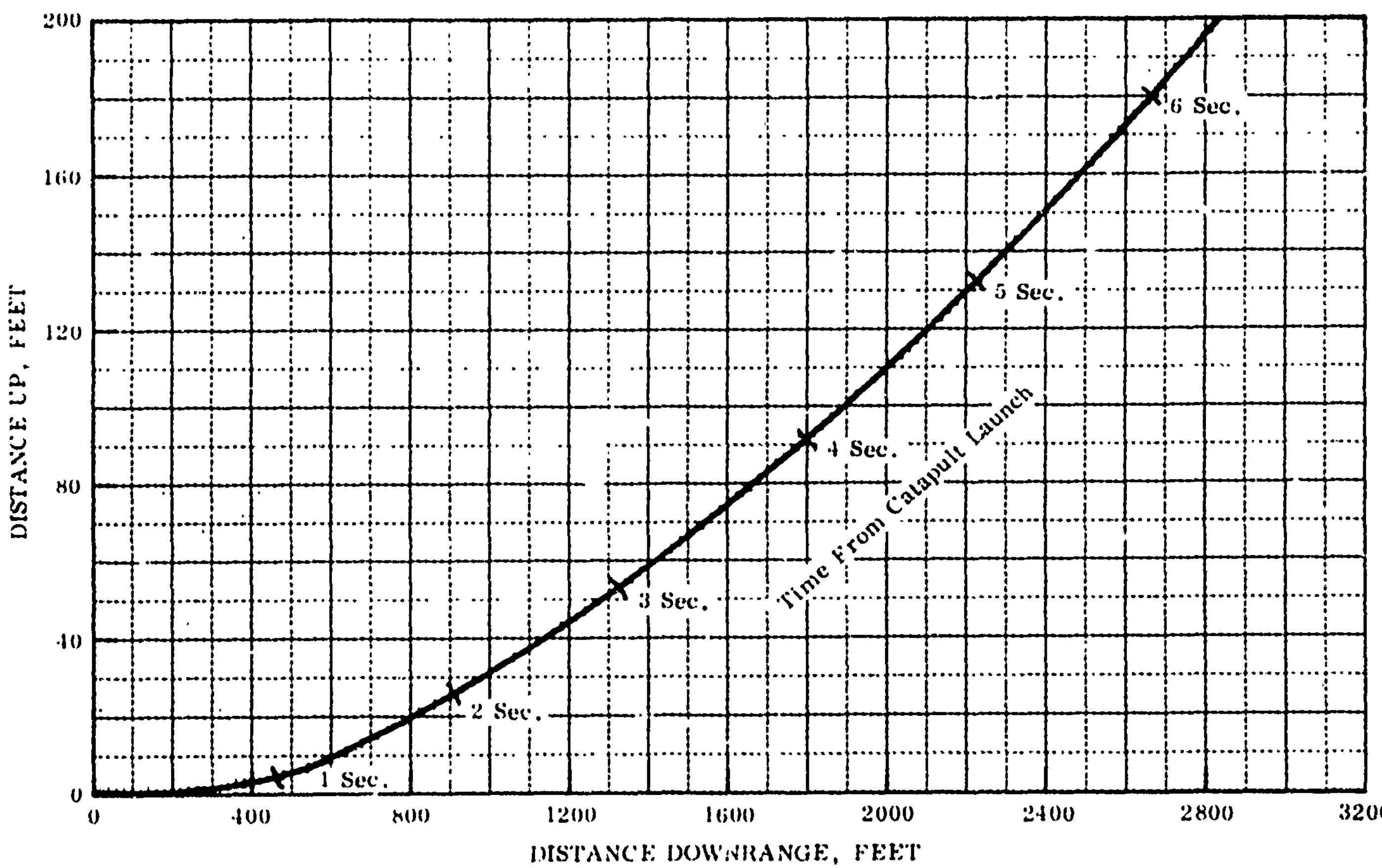


Figure 2-38. Worst Case Trajectory (BQM-34F Catapult Launch)

i. The effect of lateral asymmetries on a good launch is to increase the minimum launch velocity from 420 to 450 feet per second.

j. Zero lift pitching moment variations show that while the simulation model agrees well with flight data, the values used in the analysis are somewhat conservative.

k. Initial pitch rate has some effect on launch. For 10 degrees per second, the velocity can be lowered from 450 to 440 feet per second and for 20 degrees per second from 450 to 430 feet per second.

l. While the worst case was only assumed, the following conditions were checked:

(1) The forward center of gravity limit is in fact worst than aft center-of-gravity limit.

(2) 105°F at 5,000 feet is in fact worse than 59°F at sea level.

(3) Heavy aircraft launch is worse than light aircraft launch.

m. Other flight conditions will produce a flight profile where the aircraft climbs faster than the worst case shown in Figure 2-38.

n. The weight variation results for the worst case configuration and lighter weight configurations are illustrated in Figures 2-39 and 2-40 for the following configurations assuming forward center-of-gravity limits in all cases:

(1) 3,000 pounds, full fuel

(2) 2,500 pounds, full fuel

(3) 2,100 pounds, 11 pounds external fuel

(4) 1,700 pounds, no external fuel tank

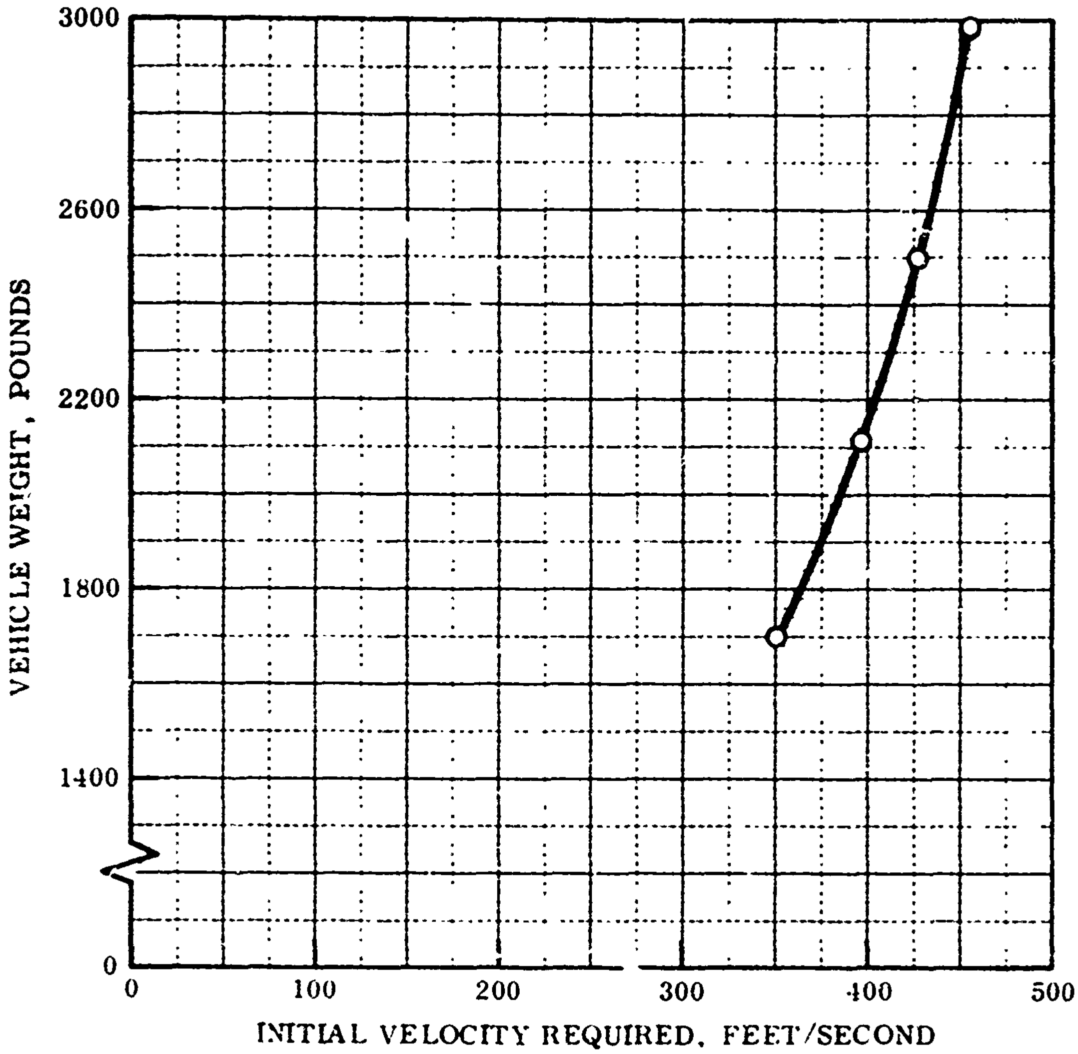


Figure 2-39. General Trend of Vehicle Weight on Velocity Requirements (BQM-34F Catapult Launch)

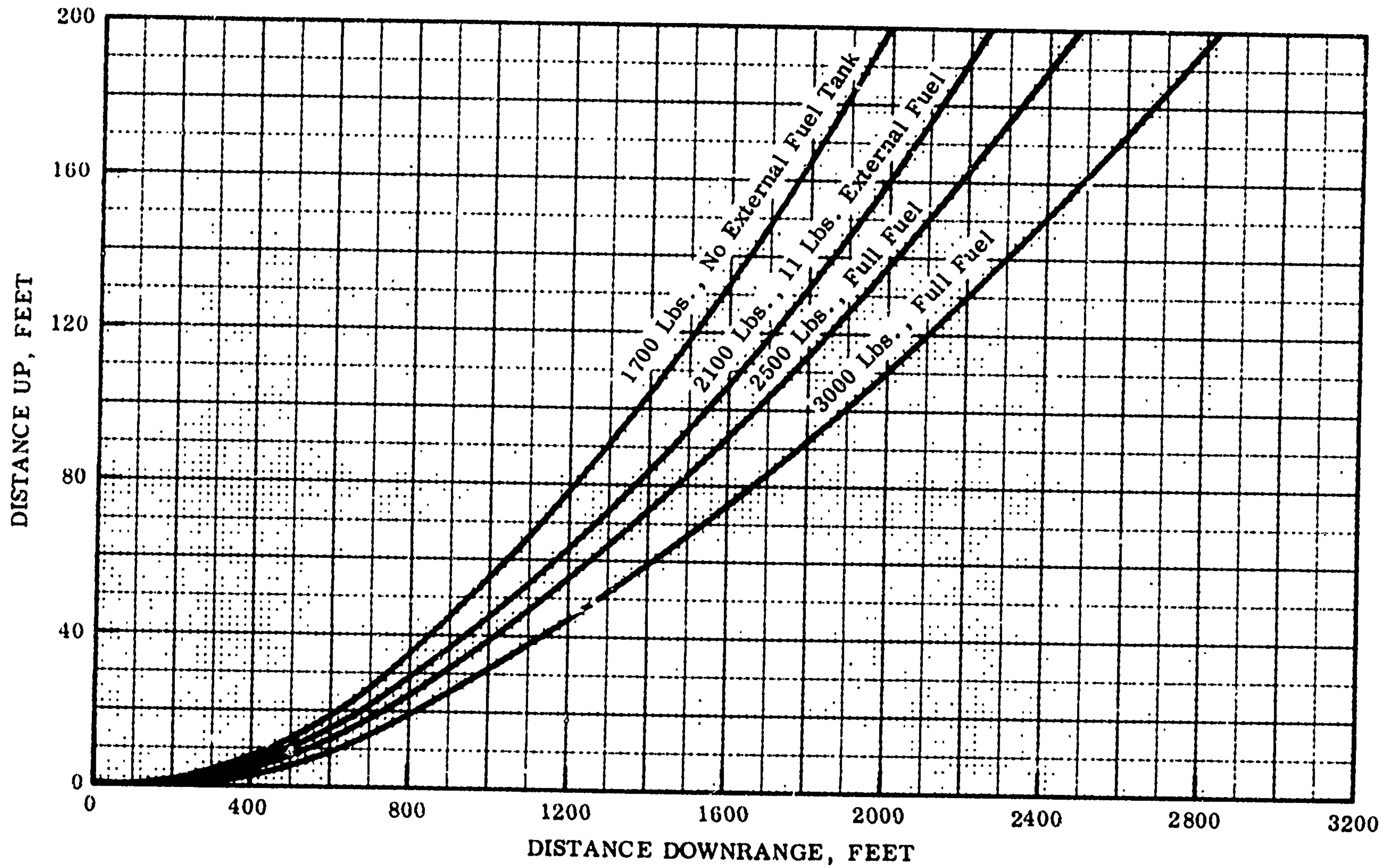


Figure 2-40. Effect of Weight on Trajectory (BQM-34F Catapult Launch)

The general trend of the required launch velocity versus vehicle weight is shown in Figure 2-39. The actual values will depend on the airframe configuration such as IR pods on or off, fuel tank on or off, center-of-gravity range, and vehicle inertias. Figure 2-40 presents the effect of reducing weight and initial velocity on the launch trajectory. The performance is better with a lower weight, even though the initial velocity is lower. The other initial launch dynamics for the lighter weight vehicle are similar to that presented for the heavy weight configuration. The 1,700-pound weight is not a very realistic condition since there is not much fuel in the vehicle.

o. Preliminary analysis showed that launching in RELEASE mode appeared to be better than launching in other modes such as CLIMB or SUBSONIC MACH HOLD mode. The autopilot command procedure (mode switching) should be considered in another study after the launch vehicles and catapult launcher configurations are determined.

Conclusions

For the assumed worst case analyzed:

a. The vehicle should be launched at 10 degrees pitch attitude with at least 450 feet per second catapult launch velocity and the engine running at 100 percent rpm.

b. No autopilot changes are required. The present ground launch pitch attitude command of 25 degrees can be used.

c. Further reductions in velocity can be made by decreasing vehicle weight or by an initial pitch rate.

3.0 REFERENCES

1. USAF Stability and Control Datcom, Section 4.2.3.1 and 4.2.3.2, July 1963.

2. Hopkins, E. J., A Semiempirical Method for Calculating the Pitching Moment of Bodies of Revolution at Low Mach Numbers, NACA RM A51C14, 17 May 1954.

3. Hoerner, S. F., Fluid Dynamic Drag, published by the author, 1965.

4. Final Stability and Control Derivatives Report, USAF XQ-2C Target Drone, Ryan Report No. 12459-1, 1 July 1959.

5. Kunzmann, R. V., Six-Degree-of-Freedom Flight Simulation Program, Report No. TRA 14754-6, 22 May 1972.

6. System Development Specification for A/A37G-9 AFSC, Lear Siegier Drawing No. 431020, Revision 8, 9 March 1973.

7. Riley, T. V., Ground Launch Design Data Stability and Control Report for BQM-34F Supersonic Aerial Target, Report No. TRA 16654-17, 19 October 1973.

8. Model 166 Estimated Installed Engine Performance Data - Ambient Temperature Matrix, IDC TS-280, 24 April 1970.

9. Standard Atmosphere, Impact Pressure, and Calibrated Airspeed Explicit Equations for Computer Programs, IDC 115/1049, dated 23 August 1973.

APPENDIX

POTENTIAL HAZARD ANALYSIS

PREP BY J. BUNGANICH	TELEDYNE RYAN AERONAUTICAL	TRA REPORT	16655-27
APP BY D. R. KRAMER		SHEET 1	OF 26
APP BY W. T. IMMENSCHUH	BQM-34A/F	REL 5/1/74	REV
		REV	REV

SUBJECT POTENTIAL HAZARD ANALYSIS OF PROPOSED CATAPULT/SPA INTERFACE

PREPARED AS PART OF DATA ITEM A002
UNDER CONTRACT F04606-73-A-0048/SC18

APPROVED BY: F X Marshall DATE: 5-7-74
F. X. Marshall
Director, Target Programs & Services

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R. A. Petrofsky
Program Manager - Subsonic Targets

APPROVED BY: B F Owens DATE: 5-7-74
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Program Manager - Supersonic Targets

R-550-13

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1.0 INTRODUCTION

1.1 Purpose - The purpose of this report is to document the results of a study that was conducted by Systems Safety Engineering Group. The purpose of this study was to identify any potential Category III or IV hazards to equipments and/or personnel associated with a yet to be designed catapult - launcher for BQM-34A/BQM-34F Teledyne Ryan SPA.

1.2 Scope - The scope of this study was limited to potential hazards that could be associated with a SPA/catapult interface. This catapult is to be designed, manufactured and tested by a still to be determined contractor. Safety design criteria given in this report should be considered wherever appropriate in order to eliminate, reduce or control hazards that could be associated with this SPA/catapult interface.

In as much as no specific information is available on the catapult and its equipments at this time, this analysis is necessarily of a general nature and addresses itself to past experiences in other methods of launching a SPA. It has been found that the same general types of hazards exist regardless of the type of energy, equipments and procedures that are utilized to bring a SPA to acceptable launch conditions.

1.2 (continued)

The potential hazard analysis was conducted without the benefit of any other Preliminary Hazard Analysis (PHA), System Hazard Analysis (SHA) or Subsystem Hazard Analysis (SSHA), of either the basic BQM-34A/BQM-34F SPA or their ground launcher. Lack of this type of previous analysis further detracts from any specific details in this report.

This report is prepared for submittal and approval as a supplement to another Technical Report, Data Item A002 of Contracts Data Requirements List (DD1423) dated 7 February 1974 Contract No. F04606-73-A-0048.

1.3 Procedure - The following basic steps and preliminary analyses were taken in developing this report:

a. A review was made of problems known through experience on similar SPA and other techniques of launching to determine whether they could also be present in this type of SPA/Catapult interface.

b. Assumptions were made of the possible use, environments and basic performance characteristics of a catapult to determine the overall spectrum of possible hazards that might be present.

1.3 (continued)

c. A catapult system of launching TRA's SPA was never utilized; therefore, an in-house survey of personnel who had previous experience with manned aircraft catapult systems (steam, hydraulic and explosive charge) was made to explore any similarity of hazards that might also be inherent in the proposed SPA catapult system.

d. Information on operational and accident experience pertaining to other catapult systems was requested on 28 March 1974 by ASD/RWDO from the following sources in order to obtain statistical accident and failure information rate:

U. S. Naval Safety Center
NAS Norfolk, Va.

Air Force Flight Dynamics Laboratory?FEM
Wright-Patterson Air Force Base
Ohio 45433

Naval Air Engineering Laboratory
NAEC Naval Base
Philadelphia, Pa. 19112

All-American Engineering Company
Development Division
801 South Madison Street, Box 124/
Wilmington, Delaware 19899

As of this writing, no information has been received to assist in this analysis. In the event data is received that would add to or change anything presented in this report, it will be submitted as an attachment to this analysis.

1.4 Basic Assumptions

1.4.1 The qualitative nature of this analysis indicates that the identification of potential hazards associated with this interface be premised upon experience on other somewhat similar systems or subsystems rather than upon all conceivable conditions, situations and failures.

1.4.2 No specifics are available as to the actual type of catapult and its associated equipments, AGE and procedures; therefore, the approach to this study is of a broad brush, general nature survey in order to catalog not only the obvious potential hazards but some insidious ones that might escape the designer not familiar with past problems in this area.

1.4.3 It was also assumed during this analysis that no modifications will be made to the SPA; therefore, the various hazards associated with the SPA/launcher interface must be taken into consideration during the design of the catapult itself.

1.4.4 Only Category III and IV hazards were considered during this analysis. Paragraph 2.1 defines these categories as taken from MIL-STD-882 and made applicable to unmanned aircraft.

2.0 FINDINGS

2.1 Hazard Categories as more explicity defined below generally conform to these listed in MIL-STD-882. These categories have been applied to the potential hazards as listed in Table I.

Category I - Minor damage to SPA or launcher/equipments, consequences to normal operation damage less than 2% of cost of SPA/catapult.

Category II - Moderate damage to SPA/catapult, major component, or minor injuries (non-hospitalization) to personnel.

Category III - Major damage to SPA launcher and associated equipments/facilities, serious injury to personnel, and others not part of the operation.

Category IV - Catastrophic loss of SPA, launcher or associated equipments, ground facilities and/or permanent crippling injuries or death of personnel.

2.3.4 The third column identifies the hazard effect (the consequence(s) of the undesirable event). In addition, a numeral index of the relative probability of occurrence is in parentheses for the hazard effect as defined in paragraph 2.2.

2.3.5 The fourth column indicates hazard category as defined in paragraph 2.1.

2.3.6 The last column titled REMARKS presents a preventative or corrective measure that should be taken into consideration in order to prevent or minimize the hazard. These predetermined actions and/or procedures are premised upon experience with other somewhat related systems and might prevent either the occurrence of the hazardous condition or its consequences.

2.2 Numerical Index of the Relative Probability of occurrence shown below is an attempt to qualitatively estimate how often a particular hazard effect will occur given that the hazard is present. Th. · numerical index is shown in the third columns of Table 1.

Numerical Index	Qualitative Estimate of Occurrence	Order of Magnitude Estimate of Occurrence
1	Extremely Low	One in a Million
2	Very Low	One in a Hundred Thousand
3	Low	One in Ten Thousand
4	Moderately Low	One in a Thousand
5	Moderately High	One in a Hundred
6	High	One in Ten
7	Very High	Fifty-Fifty

2.3 Potential Hazard Matrix

2.3.1 Table 1 is a tabulation of the potential hazards found in the conduct of this analysis.

2.3.2 The sequence number given in the first column is provided for identification purposes only and does not denote any priority or sequential nature of the potential hazard defined.

2.3.3 The second column describes the potential hazard (situation, condition or action which leads to an undesirable event).

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No.	Potential Hazard	Hazard Effect	Cat.	Remarks
1	OUT OF TOLERANCE ALIGNMENT BETWEEN SPA/CATAPULT.	POSSIBLE LOSS OF SPA DURING LAUNCH PHASE DUE TO MIS-ALIGNMENT. (6)	IV	DESIGN SHOULD PREVENT ANY INADVERTENT GROSS MIS-ALIGNMENTS. USE OF ACCURATE AND CALIBRATED ALIGNMENT AGE.
2	COMPLICATED AND OVERLY INVOLVED SET-UP AND ALIGNMENT PROCEDURES REQUIRING EXPERIENCED AND VERY WELL TRAINED PERSONNEL.	POSSIBLE LOSS OF SPA DUE TO INADEQUATE TIME, TRAINING AND/OR LACK OF EXPERIENCED AND SUPERVISORY PERSONNEL. (5)	IV	(A) ALIGNMENT PROCEDURES SHOULD BE SIMPLIFIED AND ABLE TO BE ACCOMPLISHED BY RELATIVELY INEXPERIENCED PERSONNEL WITH UNSOPHISTICATED AGE. (B) ALIGNMENT PROCEDURES SHOULD NOT BE OVERLY INVOLVED AND TIME CONSUMING.
3	MALFUNCTION OR FAILURE OF HANDLING EQUIPMENT WHILE UPLOADING OR DOWNLOADING SPA ON CATAPULT DOLLY.	(A) MAJOR STRUCTURAL DAMAGE TO SPA AND/OR CATAPULT EQUIPMENTS. (B) SERIOUS PERSONNEL INJURY. (5)	III	GFE (OUTSIDE THE SCOPE OF THIS ANALYSIS).

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
4	CARELESS OR IMPROPER OPERATION OF HANDLING EQUIPMENT DURING UP-LOAD OR DOWN-LOAD OF SPA ON CATAPULT DOLLY.	(A) MAJOR DAMAGE TO SPA AND/OR CATAPULT EQUIPMENTS. (B) SERIOUS PERSONNEL INJURY. (5)	III	(A) PROCEDURAL INSTRUCTIONS SHOULD BE SPECIFIC WITH APPROPRIATE CAUTIONS/ WARNINGS. (B) USE TRAINED PERSONNEL WITH PROPER SUPERVISION AND SAFETY MONITORS DURING PARTICULARLY HAZARDOUS STEPS IN THE UP (OR DOWN LOAD) CYCLE.
5	FAILURE OF VEHICLE HOLD BACK DURING ENGINE RUN CAUSING A "RUNAWAY DOLLY".	SERIOUS DAMAGE OF SPA IF NOT PROPERLY ARRESTED. (6)	III	(A) CONDUCT TESTS TO DEMONSTRATE HOLLBACK CAPABILITY. (B) CONDUCT TESTS TO DEMONSTRATE ARRESTING CAPABILITY OF SPA/DOLLY VEHICLE.

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No.	Potential Hazard	Hazard Effect	Cat.	Remarks
6	IMPROPER CABLING AND UMBILICAL CONNECTIONS.	POSSIBLE LOSS OF SPA DURING LAUNCH PHASE. (6)	IV	(A) ALL CABLING BETWEEN SPA AND LAUNCHER SHOULD BE DESIGNED TO BE ROUTED IN ONE WAY ONLY WITH NO CHANCE OF MIS-MATCH, SHORT, DISCONNECT, INTERFERENCE OR FAILURE AT A CRITICAL PHASE JUST PRIOR TO OR DURING THE LAUNCH.
7	INSUFFICIENT CATAPULT RELEASE SPEED RESULTING IN STALL OF SPA (END SPEED BELOW V_{STALL} OF SPA).	LOSS OF TARGET (7)	IV	CATAPULT DESIGN TO INCLUDE CAPABILITY TO ACCURATELY MONITOR AND CONTROL END SPEED OF SPA FOR ALL CONDITIONS OF WEIGHT, TEMP./ ALT. AND WIND CONDITIONS. IF AN ABORT CAPABILITY IS NOT PART OF INITIAL DESIGN, CONSIDERATION SHOULD BE GIVEN FOR SOME TYPE OF CONTROLLED ARRESTMENT OF SPA/ DOLLY WITH MINIMUM DAMAGE AND NO HAZARD TO PERSONNEL.

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POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
8	INCORRECT SETTINGS PUT INTO CATAPULT CONTROL PANEL TO COMPENSATE FOR DIFFERENCES OF TEMPERATURE, WIND CONDITIONS, SPA WEIGHT, ENGINE THRUST, ETC.	POSSIBLE LOSS OF SPA DURING LAUNCH (5)	IV	(A) SETTINGS PUT INTO ANY TYPE OF "CATAPULT CONTROL PANEL" SHOULD BE DISPLAYED FOR THE LAUNCH CONTROL OFFICER. (B) THESE SETTINGS SHOULD BE DISPLAYED AS MATCHED-UP WITH ACTUAL, REAL-TIME CONDITIONS.
9	PREMATURE RELEASE OF VEHICLE HOLD BACK BEFORE THE TENSION LEVEL OF CATAPULT HAS REACHED A PRE-DETERMINED LEVEL.	POSSIBLE LOSS OF SPA DUE TO INSUFFICIENT END SPEED. (6)	IV	(A) THE HOLD BACK FITTING SHOULD BE DESIGNED TO RELEASE (RUPTURE IN TENSION) AT SOME PRE-DETERMINED TENSION LOAD. (B) THIS HOLD-BACK FITTING MIGHT BE COLOR-CODED TO INSURE CORRECT ONE IS USED FOR A SPECIFIC CONDITION.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
10	STRUCTURAL FAILURE OF SPA/ CATAPULT DOLLY INTERFACE DURING ENGINE RUN OR LAUNCH.	POSSIBLE LOSS AND MAJOR DAMAGE TO CATAPULT LAUNCHER. (5)	IV	LOADS IMPOSED DURING THE LAUNCH NOT TO EXCEED THE EXISTING RATO ATTACHMENTS LIMITS. (SEE FINAL REPORT FOR ANALYSIS OF LIMIT LOADS.)
11	ACCIDENTAL EJECTION OR RETRACTION OF UMBILICALS.	INJURY TO MAINTENANCE PERSONNEL OR DAMAGE TO EQUIPMENTS. (4)	III	(A) PROVIDE POSITIVE SAFETY LOCKING DEVICES THAT SHOULD BE INSTALLED DURING MAINTENANCE OPERATIONS. (B) THESE SAFETY LOCKING DEVICES SHOULD HAVE RED "REMOVE PRIOR TO LAUNCH" STREAMERS ATTACHED TO INSURE REMOVAL.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
12	CATAPULT ATTACHMENT FAILS TO RELEASE FROM SPA AT REQUIRED RELEASE POINT.	CATASTROPHIC LOSS OF SPA WITH MAJOR DAMAGE TO CATAPULT EQUIPMENTS. (5)	IV	(A) DESIGN SHOULD BE FAIL SAFE. RELEASE SHOULD <u>NOT</u> BE DEPENDENT ON ANYTHING BUT ADEQUATE FLYING SPEED. (B) PERFORM TESTS TO DEMONSTRATE THAT SPA WILL BE PROPERLY RELEASED.
13	MALFUNCTION OF UMBILICAL EJECTION/RETRACTION MECHANISM DURING LAUNCH PHASE.	DAMAGE TO UMBILICAL MECHANISM OR SPA. (6)	III	THE S.O.W. PROHIBITS ANY MODIFICATION ON VEHICLE. THE CATAPULT MANUFACTURER MUST PROVIDE PROVISIONS TO ACCOMMODATE EXISTING METHOD OF UMBILICAL RELEASE.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
14	SPA STRIKES CATAPULT AS IT IS RELEASED AT END OF POWER STROKE.	POSSIBLE LOSS OF SPA IF THE DRAG OR MAIN CHUTE CANS STRIKE SOME PART OF CATAPULT EQUIPMENTS. (5)	IV	(A) INSURE THAT THERE IS A POSITIVE SEPARATION OF SPA AND CATAPULT DOLLY AT INSTANT OF RELEASE. (B) PERFORM TESTS WITH DUMMY LOAD ON CATAPULT TO DEMONSTRATE SAFE AND POSITIVE SEPARATION.
15	CATAPULT INTERFACE WITH SPA INDUCES A PITCHING, ROLLING OR YAWING MOMENT TO SPA AT RELEASE.	SPA'S FLIGHT CONTROL SYSTEM MIGHT NOT BE ABLE TO COMPENSATE FOR THE VARIOUS COMBINATIONS OF MOMENTS AT THE LOW END-SPEED. LOSS OF SPA IF BEYOND LIMITS OF FLIGHT CONTROL SYSTEM. (6)	IV	(A) CATAPULT DESIGN TO INSURE THAT THESE MOMENTS IMPARTED TO SPA (IN ALL CONFIGURATIONS) ARE IN THE SPA'S CONTROL EFFECTIVENESS RANGE WITHIN THE LAUNCH ENVELOPE.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
16	ACCIDENTAL RELEASE OF ANY HIGH ENERGY SOURCES THAT ARE BEING STORED TO PROPEL THE CATAPULT (GAS, STEAM, HYDRAULIC OR MECHANICAL STORED ENERGY SUCH AS INERTIA WHEEL).	SERIOUS INJURY OR LOSS OF LIFE. (6)	IV	(A) PROCEDURES MUST BE DEVELOPED TO INSURE THE ENERGY SOURCE USED TO LAUNCH THE SPA, IS ADEQUATELY CONTROLLED, PROTECTED AND SAFE-GUARDS INCORPORATED TO PREVENT ACCIDENTAL RELEASE. (B) DESIGN SHOULD BE SUCH THAT ENERGY SOURCE <u>NOT</u> BE COUPLED TO SPA/DOLLY UNTIL ALL PERSONNEL ARE CLEAR OF DANGEROUS AREAS.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

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No.	Potential Hazard	Hazard Effect	Cat.	Remarks
17	ADVERSE ENVIRONMENTAL CONDITIONS SUCH AS HEAVY RAIN, DUST OR FREEZING CONDITIONS ON AN EXPOSED SPA/LAUNCHER.	POTENTIAL MALFUNCTION OF CATAPULT AND RESULTANT DAMAGE OR DESTRUCTION OF SPA (5)	IV	(A) ADHERE TO ENVIRONMENTAL SPECIFICATION REQUIREMENTS. (B) ANALYSIS AND FUNCTIONAL TESTING SHOULD BE CONDUCTED UNDER VARIOUS PREDICTED OPERATIONAL ENVIRONMENTAL CONDITIONS. (C) PROTECTION OF CRITICAL PARTS AND COMPONENTS FROM MOISTURE, DUST, ETC.

POTENTIAL HAZARD ANALYSIS SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
18	INADEQUATE IDENTIFICATION AND CONTROL OF POTENTIAL HAZARDOUS EQUIPMENTS, CONDITIONS, OPERATIONS OR AREAS PERTAINING TO THE SPA/LAUNCHER COMPLEX.	SERIOUS PERSONNEL INJURY. (4)	III	(A) INSTALL APPROPRIATE WARNING & CAUTION SIGNS. (B) PROVIDE PROTECTIVE PERSONNEL BARRIERS TO KEEP UNAUTHORIZED PERSONNEL OUT OF A SPECIFIC AREA. (C) PROVIDE SAFETY INTERLOCKS OR CUT-OUT CIRCUITRY TO CONTROL EQUIPMENTS THAT COULD BE HAZARDOUS TO PERSONNEL. (D) TECH DATA ON CATAPULT LAUNCHER SHOULD PROVIDE A SUMMARY SECTION OF ALL HAZARDOUS EQUIPMENTS THAT PERSONNEL SHOULD BE SPECIFICALLY AWARE OF.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
19	CATAPULT DESIGN RESULTS IN SPA MAINTENANCE, SERVICING, AND INSTALLATION DIFFICULTIES.	POTENTIAL OF INJURY OR DAMAGE TO SPA AND/OR LAUNCHER AS PERSONNEL TAKE SHORT CUTS OR ESTABLISH JURY RIGS TO WORK AROUND THESE DIFFICULTIES. (4)	III	DESIGN SHOULD ALLOW EASY ACCESS TO ALL COMPONENTS OF SPA/CATAPULT THAT WILL REQUIRE MAINTENANCE, SERVICING OR ADJUSTMENT.
20	JET ENGINE EXHAUST IMPINGEMENT ON CRITICAL PARTS OF CATAPULT ASSEMBLY.	MAJOR DAMAGE TO CATAPULT COULD CAUSE A MALFUNCTION DURING LAUNCH. POTENTIAL OF LOSS OF SPA. (4)	III AND/OR IV	DESIGN SHOULD PROVIDE FOR ADEQUATE SHIELDING AND BLAST DEFLECTORS TO INSURE THAT CRITICAL PARTS OF LAUNCHER ARE NOT AFFECTED BY THE HEAT OR JET EXHAUST.
21	FIRE IN SPA OR AROUND CATAPULT DUE TO FUEL VENTING, SPILLAGE OR IMPROPER ENGINE START OR SECURE.	LOSS OF SPA AND MAJOR DAMAGE TO CATAPULT IF FIRE CANNOT IMMEDIATELY BE CONTROLLED WITHOUT ENDANGERING PERSONNEL. (6)	IV	INSTALL FIRE SUPPRESSION SYSTEM AND MEANS CAPABLE OF CLEARING SPILLED FUEL & EXTINGUISHING ANY FIRE.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks.
22	BLAST DEFLECTOR IS INADVERTENTLY DROPPED WHILE PERSONNEL ARE WORKING IN THIS AREA.	SERIOUS INJURY TO OR DEATH OF PERSONNEL IF STRUCK BY BLAST DEFLECTOR. (5)	IV	PROVIDE POSITIVE LOCKING OF ANY TYPE OF MOVABLE BLAST DEFLECTOR WHILE IN "UP" POSITION BY INSTALLATION OR REMOVABLE PIN. THIS PIN TO HAVE "REMOVE PRIOR TO LAUNCH" STREAMER ATTACHED. INCORPORATE APPROPRIATE WARNINGS IN TECH. DATA.
23	POSSIBILITY OF LAUNCHING SPA WITH BLAST DEFLECTOR IN WRONG POSITION. FAILURE MODE WOULD BE CATAPULT FIRE SWITCH THAT IS ALREADY FAILED CLOSED AT THE TIME A LAUNCH COMMAND IS GIVEN.	SPA WOULD BE CATAPULTED BEFORE DEFLECTOR RETRACTS OUT OF THE WAY. MAJOR DAMAGE TO SPA/LAUNCHER. (5)	III	DESIGN INTERLOCK CIRCUIT TO INSURE BLAST DEFLECTOR IS FIRMLY SECURED IN CORRECT POSITION BEFORE SPA CAN BE CATAPULTED.

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POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
	FOD (FOREIGN OBJECT DAMAGE) TO SPA DURING ENGINE RUN OR CATAPULT STROKE.	ENGINE MALFUNCTION. POSSIBLE LOSS OF SPA. (4)	IV	DESIGN SHOULD INSURE THAT FOD DAMAGE TO SPA CANNOT OCCUR DURING ENGINE RUN OR LAUNCH. SCREENS, BAFFLES AND/OR DEFLECTORS SHOULD BE CONSIDERED IN CATAPULT DESIGN.
25	MISLAID TOOLS, RAGS, CLEANING AGENTS, OR LOOSE SUPPORT EQUIPMENT ON OR AROUND LAUNCHER.	SERIOUS INJURY TO PERSONNEL OR MALFUNCTION OF CATAPULT OPERATION. (5)	III	INCLUDE WARNING NOTE IN PROCEDURES. PROVIDE INSPECTION ITEM FOR LCO IN PRE-LAUNCH CHECK LIST. PROPER SUPERVISION AND MAINTENANCE PRACTICES AROUND SPA AND CATAPULT AREA.

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POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
26	FAILURE TO PULL ALL SAFETY PINS PRIOR TO CATAPULT.	POSSIBLE LOSS OF SPA WITH MAJOR DAMAGE TO CATAPULT. (5)	IV	LCO TO PERFORM INVENTORY OF PINS AS PART OF CHECK-LIST PRIOR TO CATAPULTING. ALL PINS TO HAVE RED "REMOVE PRIOR TO FLIGHT" STREAMERS ATTACHED.
27	INADVERTENT RELEASE OF CHUTES DURING THE CATAPULT LAUNCH PHASE.	LOSS OF SPA (5)	IV	DESIGN SHOULD INCORPORATE SOME TYPE OF LOWER LANYARD SWITCH TO PROVIDE FOR LOCK-OUT OF RECOVERY SYSTEM DURING THE CATAPULT LAUNCH.

POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
28	CUTTER PULSE DOES NOT FIRE RESTRAINING CABLE CUTTER TO SEPARATE SPA FROM DOLLY.	SPA WOULD NOT BE RELEASED EVEN THROUGH IT HAS ACHIEVED ADEQUATE LAUNCHING VELOCITY. POSSIBLE MAJOR DAMAGE TO CATAPULT AND SPA. (5)	III	IF THE FIRE SIGNAL IS ELECTRONICALLY GENERATED AS A FUNCTION OF RELATIVE VELOCITY, THERE SHOULD BE SOME TYPE OF MECHANICALLY GENERATED "RELEASE PULSE" AS THE DOLLY/SPA PASSES A PRE-DETERMINED POINT ON THE LAUNCHER. (IT IS ASSUMED THAT NO ABORT CAPABILITY EXISTS.)
29	AUTOMATIC BRAKING SYSTEM MALFUNCTIONS.	DOLLY IS NOT DE-CELERATED AFTER RELEASE OF SPA CAUSING MAJOR DAMAGE TO CATAPULT. (5)	III	DESIGN SHOULD CONSIDER A BACK-UP BRAKE DESIGN OR PRO-VIDE FOR A SAFE OVER-RUN AFTER LEAVING LAUNCHER RAILS.

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POTENTIAL HAZARD ANALYSIS

SPA/LAUNCHER INTERFACE

No.	Potential Hazard	Hazard Effect	Cat.	Remarks
30	THE TURBINE WHEEL PLANE OF SPA'S ENGINE IS CLASSIFIED AS A DANGER AREA DUE TO THE POSSIBILITY OF TURBINE BLADES BEING EJECTED DURING ENGINE RUN.	POTENTIAL OF TURBINE BLADES/SHRAPNEL BEING HURLED AGAINST VULNERABLE SECTIONS OF CATAPULT. POSSIBLE SERIOUS INJURY TO PERSONNEL. (4)	III	THE DANGER AREA SHOULD BE SHIELDED AND AVOIDED.
31	CABLES, ROPES OR TAPES THAT TRANSMIT ENERGY TO DOLLY ARE EXPOSED OR INSUFFICIENTLY COVERED.	SERIOUS INJURY TO PERSONNEL (4)	III	ADEQUATE GUARDS AND WARNING SIGNS SHOULD BE UTILIZED. INTERLOCKS SHOULD KEEP THE ENERGY INPUT DEVICES AND CLUTCHES FROM BEING ACTUATED IN THE EVENT THESE GUARDS ARE REMOVED.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 This analysis shows that there are a number of hazardous aspects associated with a SPA/launcher interface and all of these potential hazards should be considered in order to formulate design criteria for the proposed catapult launcher. Most of these can be eliminated and controlled by proper design. Others that are beyond reach due to cost and other restraints should be identified in tech data and controlled via appropriate restrictions, procedures and warnings to a degree where the risk level can be tolerated.

3.2 It is recommended that a Preliminary Hazard Analysis (PHA) be conducted on the catapult launcher once the basic design has been formulated. This analysis could be used as a departure point and further developed to insure that all hazardous situations have been explored and taken into consideration during the design. Prior to production and operational use of this catapult launcher, an Operational Hazard Analysis (OHA) should be conducted to verify what operating functions could be inherently hazardous to equipment and/or personnel. Results of this analysis would point out any hazardous situations that were not eliminated during design and would provide final inputs for tech data.